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Symposium on Sports Injuries

Introduction

THE reason for the existence of this Symposium lies in certain self-evident truths: healthy minds and healthy bodies are inseparable, the playing field is much to be preferred to the tavern, and the competitive spirit which has made America great does not lend itself to regimented mass exercise programs characteristic of certain old-world cultures.

It is equally obvious that wherever this spirit is exercised—on green fields, polished floors, or ice or snow—sooner or later injury will occur. This is a fact which until relatively recently has received little attention from those responsible for the athletic programs of our youth (and the young in heart). Vast sums are spent on stadiums, gymnasiums, equipment and coaching, but all too often the problems of prevention, diagnosis and treatment of injuries sustained in sport are relegated to a back room and a footnote in the annual budget.

"Athletics for all" is, happily, becoming a universal concept, and as participation increases the responsibilities of the medical profession will increase.

It is quite true that most athletic injuries are not serious, will heal despite even bizarre treatment, and leave no souvenir of permanent disability, but the day of regarding this field as "minor" and beneath the dignity of a proper doctor is gone. The late Elliott Carr Cutler expressed it well: "There is no minor surgery, but unfortunately there are many minor surgeons."

Trauma is trauma whether incurred on the highway or the playing field. The doctor who assumes responsibility for athletic injuries will be richly rewarded not only in human terms but also by a unique opportunity to study injuries from the moment of occurrence to full recovery. He will learn much that is directly applicable to the results of accidents occurring under less controlled circumstances, and may even contribute to the solution of the keystone problem of all surgery—the healing of wounds.

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General Considerations

Frequency and Nature of Sports Injuries

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IT behooves all coaches, trainers and team physicians to be aware of the marked increase in athletic participation in our colleges today. At Harvard almost 70 per cent of the undergraduates are participating in organized intramural, varsity, junior varsity and freshman sports. In a period of eight weeks in the fall of 1958 there were 274 scheduled and officiated contests on our playing fields and those of our opponents. Last year the winter-sports intramural program alone consisted of fifty-two hockey games, 113 basketball games and 152 squash-racquet team matches. Participants in intramural sports receive the same quality medical care as the varsity players; furthermore, records are kept on all injuries severe enough to cause the player to miss one or more practice sessions or games. A continuous record has been kept since the fall of 1932. It is important that the true incidence of injuries in organized sports be determined on a national scale. (Table I.)

TABLE I*
TOTAL NUMBER OF ATHLETES IN ORGANIZED SPORTS IN HARVARD COLLEGE FROM FALL 1932 THROUGH SPRING 1954

Season	1932–1937	1937–1942	1942–1947†	1947–1954‡	Totals
Fall	3,271	2,477	703	6,485	12,936
Winter§	1,235	1,662	280	8,895	12,072
Spring	2,112	2,720	445	7,670	12,947
Total	6,618	6,859	1,428	23,050	37,955

* Tables I through IV and Figures 3 through 10 from THORNDIKE, A. Athletic Injuries, Prevention, Diagnosis and Treatment, 4th ed. Philadelphia, 1956. Lea & Febiger.

† Since 1947–1948 the number of participants in Varsity and Junior Varsity Football has been averaged.

‡ The last period is for seven academic years rather than five.

§ The figures for winter sports include only hockey and winter track, the only major sports in that season until 1937, when swimming and basketball were made major sports.

It is essential that prompt medical attention be given injuries in contact sports. Fatalities in football are reported annually by Eastwood [2]. Last season, seventeen deaths were attributed to this sport, none among college players. In 1957 the Air Force [3] reported eighty-one deaths in sports, seventy-six of which were in water sports. In well supervised and organized sports, fatalities rarely occur. The medical examiner of New York City [4] records ninety-three deaths in sports in a thirty-two year period, as follows: baseball, forty-three cases; football, twenty-two cases; boxing, twenty-one cases; and basketball, seven cases.

Our experience over the past seventeen years is recorded in Table II.

What one might glean from this tabulation is questionable, but the great frequency is apparent: 3,453 injuries among 14,375 contestants, or approximately a ratio of one injury to every four contestants. This, however, is not the true picture for any one participant is likely to sustain more than one injury.

Fortunately, the more common types of injuries incurred in sports are not serious, approximately two-thirds being sprains, strains

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TABLE II

TOTAL CONTESTANTS AND TOTAL INJURIES AS RELATED TO TOTAL EXPOSURES*

Seasonal Sport	No. Participating†	No. of Exposures‡	No. of Injuries
Fall	3,840	3,741,477	2,170
Winter	4,268	13,989,276	470
Spring	6,267	18,320,132	813
Totals	14,375	36,050,885	3,453

* Exclusive of intramural teams, Fall 1936 through Spring 1954, excluding Fall 1942 through Spring 1946, for which complete figures are unavailable. Since 1947–1948 the Varsity and Junior Varsity Football figures have been averaged.

† Represents the average number of men participating in each sport each day.

‡ One afternoon period of practice or play for each man in each sport.

and contusions. One defines a sprain as a lesion involving ligamentous tissue, and a strain as involving muscular or tendinous tissue. The most common injury of contact sports is contusion (defined as a bruising of joint, muscle or other tissue) followed closely by sprains. (Table III.)

Distribution according to the part of the body injured is also of interest. Our statistics record that contusions of the knee and the surrounding tissues are greater in number than the ligamentous sprains, whereas in the ankle, ligamentous sprains are more frequent than contusions. (Table IV.)

TABLE III

TYPES OF INJURIES INCURRED MOST COMMONLY IN SPORTS AT HARVARD UNIVERSITY FROM FALL 1932 THROUGH SPRING 1954

Injury	1932–1937	1937–1942	1942–1947*	1947–1952	1952–1954	Totals
Sprains	636	426	210	344	86	1,702
Strains	363	287	96	145	53	944
Contusions:						
Joint	219	73	87	52	17	443
Muscle	526	350	111	60	18	1,065
Simple	281	93	103	97	22	596
Fractures and dislocations	223	232	105	181	47	788
Lacerations and abrasions	264	89	25	40	6	424
Inflammations and infections	300	131	66	48	9	554
Internal injuries	102	81	39	115	26	363
Miscellaneous	243	152	67	42	6	510
Totals	3,157	1,914	909	1,124	290	7,394

* From Fall 1943 until Spring 1946, sports were on a wartime basis with organized sports continued only informally and on a limited basis.

TABLE IV

DISTRIBUTION OF INJURIES INCURRED IN SPORTS AT HARVARD UNIVERSITY ACCORDING TO PARTS OF THE BODY

Region	1932–1937	1937–1942	1942–1947	1947–1954*	Totals
Abdomen	18	10	1	8	37
Achilles tendon	31	5	3	4	43
Ankle	344	200	125	226	895
Arm	38	35	12	15	100
Back	87	57	5	32	181
Buttock	29	10	0	3	42
Calf	147	91	48	14	300
Chest	75	48	55	35	213
Crotch	27	0	0	1	28
Elbow	53	38	21	12	124
Face	226	122	44	48	442
Feet	187	68	39	45	339
Groin	114	108	39	21	282
Hand	288	109	55	41	493
Head	182	109	71	140	502
Heel	32	8	2	3	45
Hip	58	26	0	4	88
Knee	426	301	137	273	1,137
Iliac crest	30	29	24	28	111
Neck	20	14	1	11	46
Shin	54	16	7	60	137
Shoulder	212	189	64	129	594
Teeth	14	1	0	11	26
Thigh	416	240	113	142	911
Throat	11	6	6	15	38
Viscera	35	42	16	12	105
Wrist	51	32	21	31	135
Totals	3,207	1,914	909	1,364	7,394

* The last period is for seven academic years rather than five.

All team physicians must be able to diagnose the injury and must be acquainted with its pathology, in order to administer or prescribe the appropriate treatment. The type of injury, its accurate location and its severity can be determined promptly. One never knows when a serious injury may occur, and it is inexcusable not to be alert to the signs of shock early in a rupture of the spleen or kidney. In our experience, two ruptured spleens and one ruptured kidney have been encountered among approximately 38,000 contestants. One of the most interesting cases of ruptured spleen (unrecognized at a high school in Texas but with survival), was described by a Harvard freshman sixteen months ago at the time of this writing.

The year before he had played in a high school game on Saturday, sustained abdominal trauma and was removed from the game. On Monday after the game he participated in a practice session, and in a collision with another player on a "missed assignment" was butted in the left aspect of the back in the region of the eleventh and twelfth ribs. He was knocked out and removed to the side lines. There was no doctor in attendance. With difficulty the boy reached the locker room, showered and dressed, drove himself home and promptly collapsed on the sofa. When his mother returned, he was immediately removed to a hospital and cared for. Operation revealed a ruptured spleen. Undoubtedly, this represents an injury to the spleen with a slowly leaking hemorrhage occurring on Saturday followed by a second injury on Monday, with a massive rupture and concomitant hemorrhage. I cite this case to emphasize the desirability of having the team physician on the field for practice sessions as well as for games.

Among other injuries that can be serious are those to the head. Unrecognized cerebral concussion in a player continuing to participate can result in great harm. Our records contain three cases of fracture of the skull (none serious) diagnosed originally as cerebral concussion. Neurosurgeons emphasize the dangers to which a player is exposed in contact sports; when his mental processes are not operating on the alert, a second blow to the head may have really serious consequences. The team physician, again, must exercise the keenest judgment and must know how to test the player's orientation for time and place. The lesion may be a simple concussion or a laceration with hemorrhage of the brain or a fracture, and the differential diagnosis cannot be easily made. Our neurosurgical consultant diagnosed one of our cases of cerebral concussion as a contusion of the brain.

Other serious injuries in contact sports are in the nature of fractures and dislocations. Inasmuch as the diagnosis and treatment of such lesions are fully described in well known textbooks [*5*], little will be stated herein except the importance of eliminating the possibility of a fracture immediately by roentgenographic study. Roentgenographic equipment, with a trained technician, in the medical room of a field house is essential to early diagnosis. In our experience with 624 fractures, over 60 per cent have occurred in the bones of the face, the fingers, the hands, and the toes and feet. The shoulder joint was involved in 61 per cent of 168 dislocations in our series. The Kocher maneuver for reduction of shoulder dislocations has never failed us.

The more common injuries in sports are sprains, strains and contusions. Miltner and Hu [*6*] have described the pathology of sprains and their healing. Fortunately, in sports most of the injuries to ligament, tendon and muscle are minor. However, the serious complete rupture or avulsion of a ligament or tendon does occur and must be recognized promptly. Our records disclose six cases of avulsion of the medial collateral ligament of the knee and one case of rupture of the deltoid ligament of the ankle in which surgery was performed. In over 1,700 sprains this represents a very small rate of ligamentous rupture, but in each case prompt surgical repair was required for good results.

The pathology and tissue repair of sprains, strains and contusions must be understood by team physicians. The diagnosis of the nature and location of the torn tissue and its severity are all important. Muscle, tendon and ligament are highly specialized tissues. They do not proliferate when torn and heal like epithelium of a burn or an abrasion; rather, the healing takes place by fibroblastic repair. This scarring of highly specialized tissue results in a "weak spot," deposited in the continuity of specialized fibers, hence, the likelihood of recurrent sprains and strains. The pathologic condition, therefore, is important to visualize. With the tearing of these tissues there is a tearing of interstitial and alveolar tissues carrying their blood supply. The greater the hemorrhage, the larger the hematoma or hemarthrosis and the larger the deposit of fibrous scar. Unless the hemorrhage is treated and controlled promptly, the disability period will be long, and the loss in the restoration of specialized tissue and thereby of optimum function will be greater. The pathologic condition, therefore, proceeds from hemorrhage, to formation of a hematoma, to absorption of the hematoma and to healing by fibrous scar. (Figs. 1 and 2.) Similarly, the sprinter's tendon (hamstring pull) is an intrinsically produced tear of muscle fibers, (highly vascular tissue), the healing of which results in the interruption of the continuity of muscle bundles by a fibrous scar. Therefore, the end result of

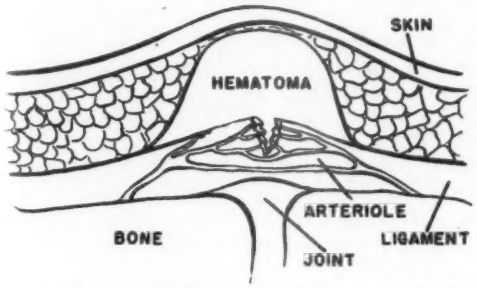


FIG. 1. Diagrammatic representation of the pathology of the acute sprain. (Figures 1 and 2 from QUIGLEY, T. B. Some observations on the prevention and treatment of athletic injuries. The American College Health Association [7].)

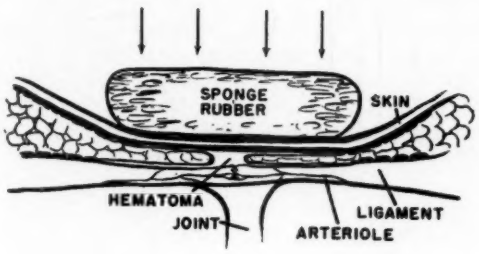


FIG. 2. Diagrammatic representation of the application of a sponge rubber compression bandage to an acute sprain.

healing in sprains and strains is a weakening in a ligament's strength or a muscle bundle's continuity. This explains the likelihood of recurrences.

From the nature of sports injuries as described herein, one can state that very few are serious. To the athlete, however, the season is short and each day lost from training due to disability is paramount; to the coach trying to develop timing and perfection in offensive team play, the loss through injury of some key blocking back is vital even for one day, and to the trainer carrying out the prescribed treatment and conditioning, the shortening by even one day of the estimated disability period is a great accomplishment. However, as Quigley has set forth in the athlete's Bill of Rights [7], to the team physician belongs the prerogative of diagnosis, treatment and prognosis. To him alone belongs the decision of when the player may return to play and with what special protective padding or strapping to guard against a recurrence.

With a knowledge of the pathology of the lesion, the treatment falls into two stages. In the first, or acute stage, therapy is aimed at instituting measures that will control hemorrhage. Whether the injury is a ruptured viscus, a contused brain, a fracture, dislocation, sprain, strain or contusion, medical attention is focused on the important and necessary factor of controlling hemorrhage. The location of the area where the primary treatment is to be carried out is the only difference. Patients with ruptured viscera, contused brains and with displaced long bone fractures should be hospitalized im-

TABLE V*
INCIDENCE OF SPRAINED ANKLES AND LENGTH OF DISABILITY INCURRED IN SPORTS AT HARVARD UNIVERSITY

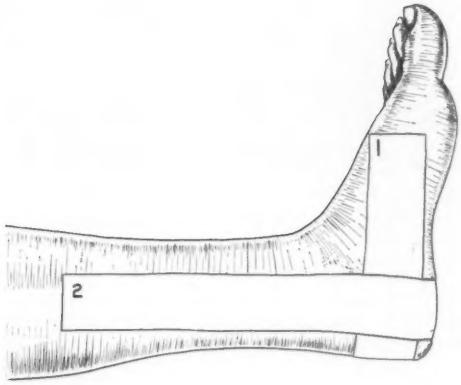
Sport	No. of Injuries		Disability Days	
	1946–1947	1953–1954	1946–1947†	1953–1954‡
Varsity football	7	2	55	35
Jr. varsity football	7	3	96	15
Intramural football	12	1	75	30
Totals	26	6	226	80

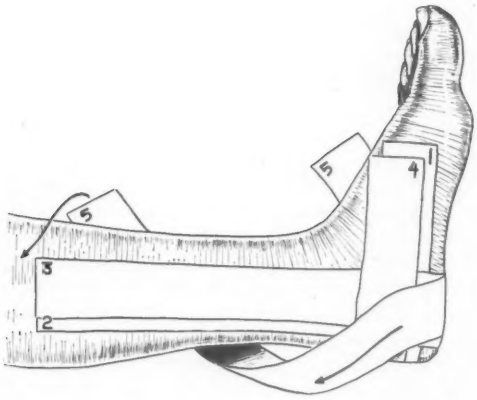
* Tables v and vi from THORNDIKE, A. Prevention of injury in athletics. *J. A. M. A.*, 162: 1128, 1956.
† Average disability, 8.69 days.
‡ Average disability, 13.33 days.

TABLE VI
INCIDENCE OF SPRAINED KNEES AND LENGTH OF DISABILITY INCURRED IN SPORTS AT HARVARD UNIVERSITY

Sport	No. of Injuries		Disability Days	
	1946–1947	1953–1954	1946–1947*	1953–1954†
Varsity football	4	5	34	46
Jr. varsity football	5	4	71	41
Intramural football	9	3	139	58
Totals	18	12	244	145

* Average disability, 13.56 days.
† Average disability, 12.08 days.





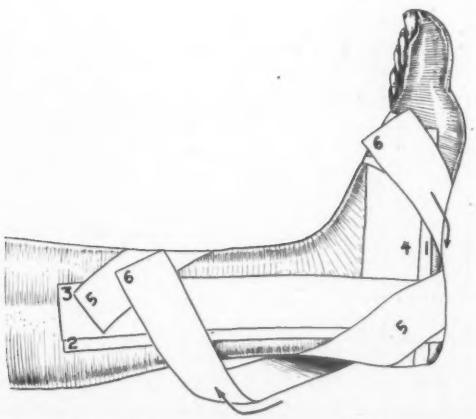
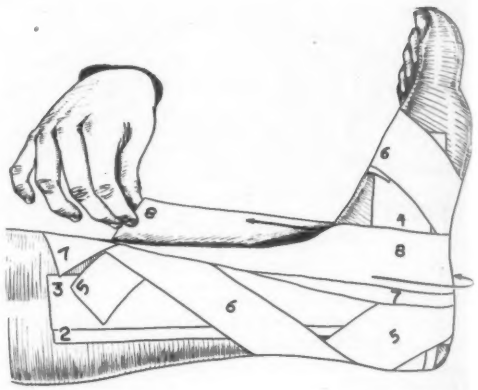


FIG. 3. First three steps of ankle strapping to prevent recurrent sprains, using the Gibney strapping as a basis.



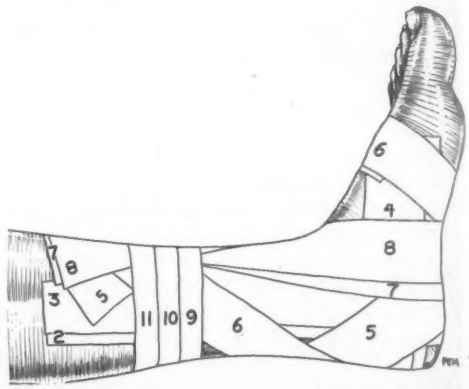


FIG. 4. Last two steps of ankle strapping to prevent recurrent sprain, using the Gibney strapping as a basis.

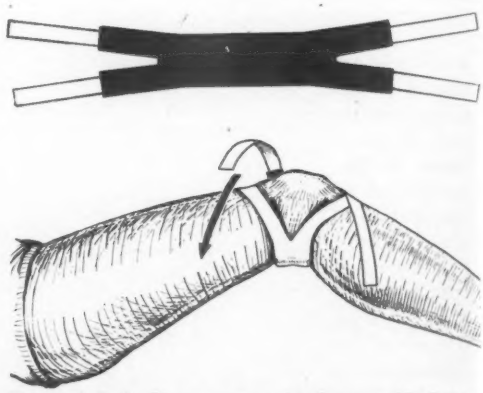


FIG. 5. A Duke Simpson strapping for unstable knees. A base of felt cut as shown above, with adhesive straps from inside of thigh to outside of thigh to inside of upper part of calf, applied as indicated in Figure 6. Lateral view.

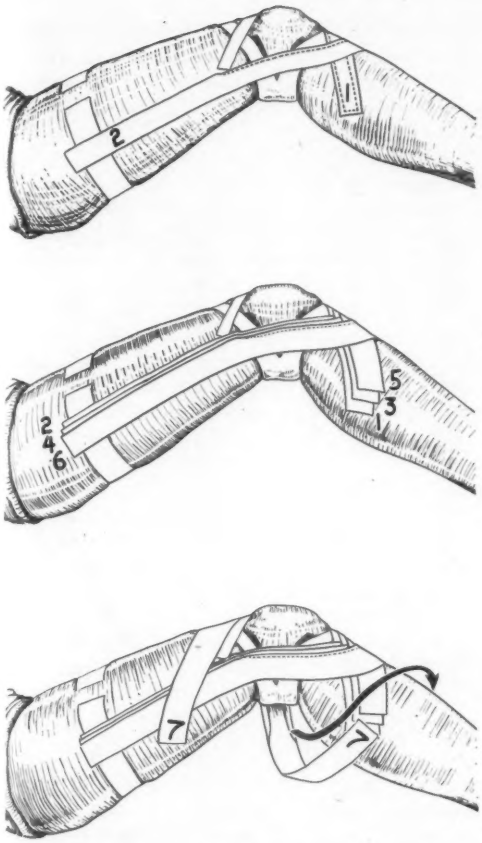


FIG. 6. First three steps of Duke Simpson strapping to prevent recurrent sprains of knee.

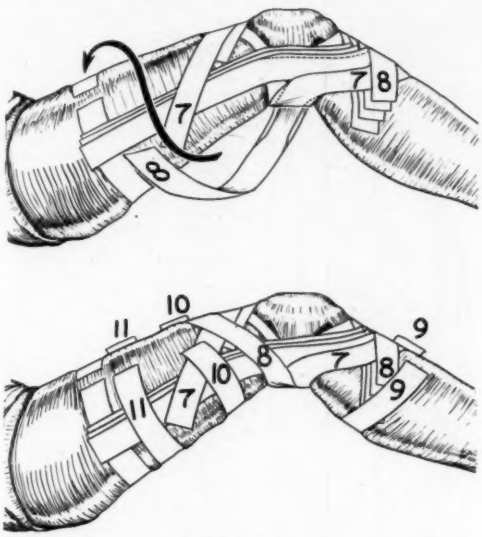


FIG. 7. Last two steps of Duke Simpson strapping to prevent recurrent sprains of knee.

mediately. The medical room of a field house should be adequately equipped with staff and equipment to take care of minor fractures without displacement, most dislocations (except those of the hips and spine), and all but an occasional and serious sprain or strain. The application of cold (ice in a wet towel), immediately after injury for half an hour, and when fracture has been ruled out, the application of a sponge-rubber compression ace bandage to the area, have provided us with a routine that has prevented many hemarthroses or many large hematomas. It has minimized hemorrhaging and has shortened the disability periods. Our experience in two football seasons selected at a seven-year interval is depicted in Tables V and VI.

If, on the other hand, hemarthrosis has developed before the patient is seen, the application of cold is of no avail. Then only can compression sponge rubber bandage be applied in some cases after arthrocentesis. The third item in the immediate treatment is rest—no weight bearing or other function of involved injured tissue for twenty-four hours. To summarize, the acute injury must be diagnosed accurately and promptly, the appropriate treatment applied and the injured part put at rest.

The second stage of treatment begins twenty-four hours later. Those patients with serious injuries requiring surgery will have been hospitalized. The less serious but more common injuries such as sprains, strains and contusions must be evaluated daily by the team physician and appropriate treatment prescribed. Reports of progress must be relayed to coach and trainers, and prognosis and treatment altered as circumstances dictate. The coach must have the utmost confidence in the doctor and trainer, otherwise suspicion will breed misgivings. The second stage of treatment of the less serious sprains, strains and contusions begins as soon as control of hemorrhage in the lesion is established, usually twenty-four hours, occasionally forty-eight hours after injury. Wherever that point may be established, treatment is focused at absorption of the waste products of hemor-

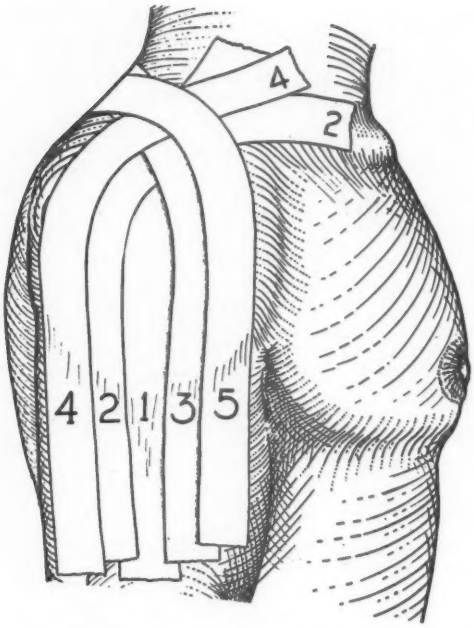


FIG. 8. Step 2 of strapping for strain of muscle or tendon or contusion.

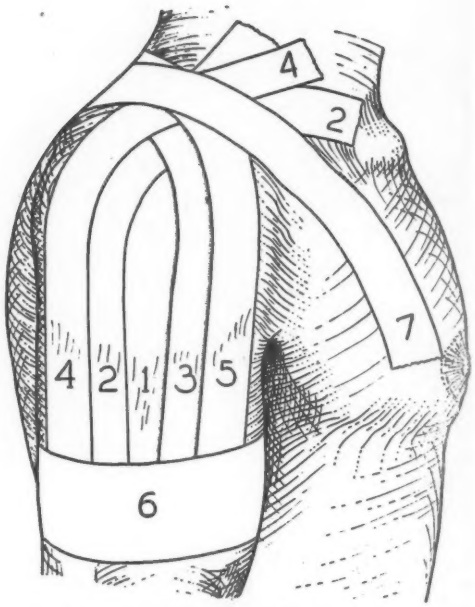


FIG. 9. Completed strapping for strain of shoulder muscle or tendon or contusion as shown in Figure 8.

rhage deposited in and around the lesion. In other words, these more common injuries require all the interest of medical and training staff. In view of the pathology and method of tissue repair of these lesions, as previously mentioned, emphasis in therapy is focused on lymphatic absorption of the waste products of hemorrhage, to minimize the deposition of fibrous scar in the traumatized tissues. The larger the scarring with the deposit of fibrous tissue in highly specialized tissues of ligament, tendon or muscle, the greater the weak spot will be. Therefore, if the size of the hematoma is limited and if the area of tissue within which it is to be absorbed is reduced, the actual scarring within the specialized tissue will be lessened. To absorb the waste products of hemorrhage, one must depend upon the lymphatic system. For this purpose one must apply heat, not only locally but to the entire area of lymphatic drainage of the extremity concerned. In our experience wet heat has been most efficacious when applied to the entire extremity including the groin in sprained ankles. Whirlpool baths not more than once a day for ten to fifteen minutes followed by effleurage of the total extremity for ten minutes are perhaps the optimum. Relative immobilization (with crutches for weight-bearing joints or with slings for lesions of the upper extremities) for a period of forty-eight to seventy-two hours is sufficient, followed by use of a cane or sling as daily evaluation may dictate. Control and evaluation of progress in convalescence must remain the prerogative of the team physician.

Complications in minor injuries occur in athletics on occasion and delay recovery. Whenever the anticipated recovery rate is slowed, one should search for the reason. A sophomore varsity football player last fall sustained a simple sprain (grade 1) of the tibiofibular ligament of the ankle, for which one would anticipate a disability period of eight or nine days. Instead it actually amounted to a period of twenty-one days. The explanation was readily obtained when the patient admitted having stumbled over a curbstone on his way to class and retraumatized the healing lesion. Most complications in a sprained joint are involved with a delay in absorption of the waste products of hemorrhage or hemorrhage extravasating in and around adjacent tendinous tissues (tendo-

vaginitis crepitans). In the knee joint however, in our experience, approximately 10 per cent of the sprains of the medial collateral ligament show injury to the meniscus, and less than 1 per cent show unrecognized osteochondritis dissecans. Complications in injuries to muscle are those of myositis ossificans [9], as well as muscular herniation through its torn fascial envelope.

The use of hydrocortisone, hyaluronidase or chymotrypsin to aid in the dissipation of the products of hemorrhage has not provided consistently good results in our experience. Our study of these hormones and enzymes has continued over a period of four years and as yet we are not prepared to report on them. Procaine hydrochloride is helpful as a diagnostic aid, but as a therapeutic agent to anesthetize a partially healed sprained ligament it is to be condemned.

From the nature of the injuries of sport, their pathology and their treatment, the team physician must determine when the repair of tissue is complete or when the player may resume participation. The criteria are well established and consist of two factors: palpable tenderness over the lesion must be absent, and function of the joint or muscle must be normal as compared to that of the opposite side. Familiarity with standard tests of joint and muscle function is essential to determine this important point accurately. Such testing has been most ably described by Kendall and Kendall [10]. In our experience the use of progressive resistance exercise on the DeLorme [11] table is a required test for function. Stationary jumping to determine the function of a recovered sprained ankle provides a simple test in comparing the normal with the injured side. In acromioclavicular separation which has been cured, testing abduction against resistance of the injured side as compared to the normal side in the vertical as well as the horizontal planes will quickly determine if full function has returned.

Because of the nature of the more common sports injuries and the serious potential of their recurrences, certain restrictive and supportive adhesive strapping are required. These must be applied daily for practice or game. The number of recurrent ligamentous sprains has been greatly reduced by the adoption of this preventive measure. The same principle can be applied to the sprinter's pulled tendon and to the acromioclavicular separation. The restrictive harness for recurrent dislocation of the shoulder is a requirement if surgical repair is delayed or refused. (Figs. 3 through 10.)

FIG. 10. Abduction limited by harness.

In conclusion one can state that the frequency of sports injuries is too great and likewise that the occurrence of deaths in sports is appalling. Colleges, high schools, recreation boards and all concerned should provide better supervision of play and better medical coverage of the sports in which the likelihood of serious injury exists. Well supervised college sports require the cooperation and team work of coaching, training and medical staff.

To avoid injury in sports, the athlete is entitled to good coaching, good equipment and good medical care, and only through the close team work of all can the best service be provided.

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Organized Medicine and Athletics: The Role of the American Medical Association Committee on Injury in Sports

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PHYSICIANS in the United States have been active as sportsmen and as medical advisers to athletes since the beginnings of organized athletics here. Until very recently there was no organized approach, however, on the part of medical associations or societies to the problems of sports medicine. This is in distinct contrast to the situation in Europe where well defined programs have been in existence for so many years that this branch of medicine has become a specialty in itself.

The original suggestion for the establishment of a Committee on Injuries in Sports was made at a meeting of Trustees of the American Medical Association in December, 1953. Exploratory contacts were made and letters sent to interested physicians which resulted in the appointment of such a committee under the chairmanship of Dr. Augustus Thorndike of Boston in 1954. The first meeting of the committee took place in Chicago in June, 1956. Since that time the committee has met regularly twice a year in different parts of the country and has undergone a few changes in its membership. Fred Hein, PH.D., of the Bureau of Health Education, has served as secretary to the committee.

Prior and subsequent to the first meeting considerable thought and discussion were devoted to the nature of the role which this committee should play. Should it be a passive spectator of events in the field, noting progress and problems and answering requests, or should it take an active part in making inquiries itself, setting standards and shaping events in the process of its activities? The decision was gradually reached to become active. Since then the press of developments has resulted in constant year-round activity conducted through the staff secretary and the chairman by correspondence with the committee members between meetings.

Although it is perhaps a little premature to speak about accomplishments in a field in which so much remains to be done, the scope of the problems with which the committee is dealing may best be understood by considering what has been done and what is in progress. Most important of all in whatever has been attempted so far has been the enthusiastic response and excellent cooperation received from representatives of the sports world, both amateur and professional, educational institutions, and the members of the medical profession as a whole.

One of the first problems which came to the attention of this committee was that of the apparently increasing number of serious and even fatal injuries to the head occurring in football players. Contact was made with a research program on the subject of protective headgear for all purposes being carried out at Cornell University under the direction of George Dye, PH.D. Discussion with representatives of the larger manufacturers of football headgear followed, and subsequently a visit was made to the laboratory of sports medicine at Michigan State University where headgear research was being carried out under the direction of Henry Montoye, PH.D. Progress has been made, not as the result of this committee's efforts but with its active encouragement in the production of a new, safer type of football helmet. It is hoped for the future that a set of test standards will be arrived at to serve as guides for the manufacture of even safer helmets. In the meantime the committee is emphasizing to those concerned the importance of buying the best head protection available and of cultivating serious respect

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for the treatment and aftercare of any type of injury to the head occurring during practice or a game.

This approach to this particular problem inaugurated the practice of making one meeting each year a visit to one of the university centers where active programs of research into the physiology of sports activities are being conducted. In 1958 the committee visited Springfield University where the program was arranged by Dr. Peter Karpovich in his laboratory. The committee hopes not only to keep informed of what is happening in such programs but also to encourage the development of new programs where appropriate facilities and qualified personnel exist.

As the scope of its inquiries widened, the committee made contacts with the National Collegiate Athletic Association (N.C.A.A.), the National Association of Intercollegiate Athletic Associations (N.A.I.A.A.) and the National Federation of High School Athletic Associations (N.F.H.S.A.A.). These contacts have been most rewarding because they are all bearing fruit.

In the first instance the N.C.A.A. appointed a special committee of its own on sports injuries and included the chairman of the A. M. A. committee as one of its members. This committee has been very active since its inception in planning and conducting a national survey of football injuries and another of training room facilities. It is currently embarking on a cooperative study of training methods with the American Olympic Committee. It has cooperated with the A. M. A. in a survey of the use of amphetamine among athletes and in the dissemination of "The Bill of Rights for the College Athlete" to all its member colleges. In these two latter projects the N.A.I.A.A. has likewise cooperated.

"The Bill of Rights for the College Athlete" was developed by the committee from an idea suggested by one of its members, Dr. Thomas B. Quigley of Boston. It is reproduced here in its entirety because it represents the committee's philosophy of correct conditions for participation in amateur athletic events.

THE BILL OF RIGHTS FOR THE COLLEGE ATHLETE

Participation in college athletics is a privilege involving both responsibilities and rights. The athlete has the responsibility to play fair, to give his best, to keep in training, and to conduct himself with credit to his sport and his school. In turn he has the right to optimal protection against injury as this may be assured through good technical instruction, proper regulation and conditions of play, and adequate health supervision. Included are:

Good coaching: The importance of good coaching in protecting the health and safety of athletes cannot be minimized. Technical instruction leading to skillful performance is a significant factor in lowering the incidence and decreasing the severity of injuries. Also, good coaching includes the discouragement of tactics, outside either the rules or the spirit of the rules, which may increase the hazard and thus the incidence of injuries.

Good officiating: The rules and regulations governing athletic competition are made to protect players as well as to promote enjoyment of the game. To serve these ends effectively the rules of the game must be thoroughly understood by players as well as coaches and be properly interpreted and enforced by impartial and technically qualified officials.

Good equipment and facilities: There can be no question about the protection afforded by proper equipment and right facilities. Good equipment is now available and is being improved continually; the problem lies in the false economy of using cheap, worn-out, outmoded or ill-fitting gear. Provision of proper areas for play and their careful maintenance are equally important.

Good medical care including: (1) A thorough preseason history and physical examination. Many of the sports tragedies which occur each year are due to unrecognized health problems. Medical contraindications to participation in contact sports must be respected. (2) A physician present at all contests and readily available during practice sessions. It is unfair to leave to a trainer or coach decisions as to whether an athlete should return to play or be removed from the game following injury. In serious injuries the availability of a physician may make the difference in preventing disability or even death. (3) Medical control of the health aspects of athletics. In medical matters the physician's authority should be absolute and unquestioned. Today's coaches and trainers are happy to leave medical decisions to the medical profession. They also assist in interpreting this principle to students and the public.

A similar program for high school athletes has been outlined under the title of "Protecting the Health of the High School Athlete." This includes a series of proposed standards for safety in competitive athletics and a guidebook for the holding of local, county or state wide conferences on this subject. The N.F.H.S.A.A. has been actively interested in this program and has further cooperated by conducting a sampling survey of health practices connected with athletic participation in its schools. The monthly bulletin of this organization contains a column on health in relation to sports which is prepared under the direction of this committee. Currently there is under consideration a series of recommendations relating to the participation of students at the junior high school level in organized football contests.

As the result of several inquiries and the specific interest of several members of the committee, a statement was issued through the *A. M. A. News* and both college athletic associations on the subject of "making weight" for wrestling and boxing events. Abuses of health involved in heroic weight reduction measures followed by strenuous competition have sometimes resulted in serious illness.

One member of the committee participated in the revision of an important pamphlet published by the Bureau of Health Education which is now entitled "Exercise and Fitness." This has a broad circulation among persons working in the field of health, physical education and recreation. Emphasis is placed on the importance of appropriate exercise in producing and maintaining physical fitness.

During the past year the committee has cooperated with the United States Olympic Committee in making recommendations of medical personnel to serve at both coming winter and summer Olympic Games of 1960. This makes the first occasion on which consultation has been sought with official representation of the profession on these selections. It represents an evident desire on the part of all concerned to see that our finest athletes get the best medical care.

In June, 1958, at San Francisco the committee presented a symposium on athletic injuries, their prevention and treatment, at the invitation of the Council for the Scientific Assembly of the Annual Meeting of the American Medical Association. Guest lecturers covered topics from skiing to skin diving. The papers were subsequently accepted for publication in the *Journal of the American Medical Association*.* In June, 1959, the committee cooperated in the presentation of a similar symposium with the Section on Orthopedics at the annual meeting of the A. M. A. in Atlantic City.

For the future it is the hope of the committee that within the scope of the A. M. A. a national organization of physicians interested in the relationship between sports and medicine, whether as team physicians, research investigators, active participants or merely fans of sport, may be established. To this end it will continue to encourage informal meetings, presentations in connection with established formal meetings and congresses, publication of articles, essays and pamphlets† and active research wherever they may be carried out. In this way there can be developed a program at least comparable and hopefully superior to any existing in other countries today.

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† Pamphlets and statements being distributed by the A. M. A. Committee on Injury in Sports: "Protecting the Health of the High School Athlete," "Johnny Makes the Team," "Making Weight," "Tackle Football in Junior High Schools," "Bill of Rights for the College Athlete" and "Safeguarding the Health of the High School Athlete."

Physical Fitness for Sports

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PHYSICAL fitness is vital to the health and happiness of our nation. Our President and other national leaders, shocked by the findings of draft examinations, have invited consultations to improve the physical condition of our youth through athletics. It is recognized that athletics are important toward this end, utilizing the instinctive desire in growing boys for physical competition. Thousands of instructors and millions of dollars are involved in our national athletic program ranging through the grade schools, colleges and into professional ranks.

The physicians of our country are responsible for determining the fitness of the individual for participation. By far the majority of the decisions are made or influenced by the judgment of the family physician. This discussion is offered as a guide in their decisions.

There are relatively few boys so handicapped as to be unable to participate in some sport. The physician should be the advisor in guiding the athlete to the activity in which he may safely participate, rather than allowing or negating some particular sport. A sympathetic understanding and explanation of the requirements and hazards of different sports following an adequate and conscientious examination places him in a psychological position to give advice to an eager, often immature youth not reached by others, especially his parents.

There is a wide range of physical stress involved in participation in the numerous competitive sports available. A marked difference exists between enjoying some lighter sport for pure recreation and participating in one of the heavier contact sports involving team victory and reputation. Three groups of sports seem apparent then: (1) those played for exercise, development and relaxation, (2) those involving organized competitive team participation and (3) professional athletics. Organized team spirit and reputation invite participation often to the point of endurance not encountered in the first group in which fatigue will usually limit the activity. On the other hand, the professional athlete is usually mature. Knowing the hazard, fully explained, he may decide to accept the risk for the financial gain or professional reputation. The less mature individual is more apt to be guided by zeal than good judgment.

The determination of fitness requires an adequate examination with the particular requirements of that sport in mind. The physician who has watched a boy grow and mature, who has a special interest in him, and who has his confidence may be able to do this in a short time. Surely a line of boys paraded hurriedly past an examiner in a noisy room represents a mere gesture. An interest in the boy and in athletics seems essential to evaluate his aptitude fairly.

As in all examinations, an adequate history is essential. We must be alerted to possible residues of previous illnesses and injuries, particularly those involving the cardiorespiratory, nervous, skeletal and renal systems. The length of disability following an injury may be a clue to its severity. Loss of consciousness, either traumatic or spontaneous, is important. The infectious diseases and their sequelae should focus our attention more sharply, and we should look for a history of drug and serum reactions. To overlook tetanus immunization may be tragic.

The examination should be thorough and unhurried but not necessarily lengthy. There are some body systems in which we are vitally interested and others in which abnormalities are not contraindications to athletics. A long involved form requiring time in examining and

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recording unimportant details invites hurry and error rather than a better estimation of the boy's ability to engage safely in athletics.

The importance of the cardiorespiratory examination is evident. All of the modalities indicated should be used. Evaluating a systolic murmur by its location, character and intensity alone is to invite error that might be avoided with roentgenograms or an electrocardiogram as an aid. The fallacy of the "athletic heart" has been exploded. The heart, like other muscles in the body, may undergo some hypertrophy with sustained exercise. There is no doubt that many cardiac neuroses have been seeded by too conservative an attitude toward a "heart murmur" by the physician. It is also an injustice to pat the boy reassuringly on the shoulder, say he has only a "functional murmur," and allow unwise strain, the penalties of which may not be manifested until years later.

The murmurs heard on examination present the most frequent and perhaps difficult problem. The history is important. It is not unusual for the boy to volunteer the information that his doctor has known of a heart murmur for years and that he has been active in sports with no difficulty in conditioning or endurance. This is reassuring. On the other hand, a murmur in a boy who has a history of "growing pains," diphtheria or scarlet fever puts the burden of proof of a normal heart upon the examiner.

Excluding active carditis, sustained participation in competitive sports may result in some apparent hypertrophy of the heart. This may be magnified on the x-ray film by the slow heart rate and increased diastolic heart volume. In the absence of a history or other evidence of heart disease, such hypertrophy with its normal or "athlete's hypertrophy pattern" by electrocardiography is not a contraindication to sports activity. In these, and other cases in which there are findings to suggest abnormality, it is often necessary to examine the heart at intervals throughout participation for evidence of a developing abnormality. If found, activity should then be moderated. Rarely must all activity be negated because of the condition of the heart. One must again remember the difference between physical exercise on the courts or fields for enjoyment and that involving competitive team effort.

There can be no dogmatic statements made about abnormal blood pressure, except a fixed high diastolic. Low pressures and slow pulses are frequently found in well conditioned athletes. There is also a tendency for increased pulse pressure after exercise, with an increased systolic or decreased diastolic reading. The rate or return to pre-exercise levels does not appear to be of prognostic importance in this group. The frequent cause of elevated systolic pressures is nervousness. Often, distracting the attention of the candidate from the examination will prove this. However, care must be taken to rule out an aortic coarctation, chronic renal disease or signs of cardiac strain. There has been no proof that exercise has any effect on early essential hypertension.

The most frequent arrhythmias encountered are sinus arrhythmias and ectopic systoles. These usually disappear with exercise and present no contraindications to exercise; *per se* they are not indicative of disease. Rapid pulse rates are usually caused by extracardial stimuli, particularly nervousness. Electrocardiogram variations, particularly in the T waves, unless typical of abnormal entities, must be correlated with the history and physical findings rather than used as sole guides. Ballistocardiograms have not proved to be of aid in evaluating the athlete's heart to date.

The most frequent cause of death in athletics is the result of injuries to the head in contact sports. It is the examiner's responsibility to determine which boys seem to be prone to injuries to the head and direct them into sports with less contact than football or boxing. There will still remain the congenital anomalies that cannot be detected by routine examinations and which likely increase the dangers of trauma.

A careful history should include the nature and severity of previous loss of consciousness. Boys with histories of a severe injury to the head with prolonged loss of consciousness or disability, those with histories of repeated concussions or who seem to suffer concussions from minor blows should be kept from the heavy contact sports. There is a rule of thumb among athletic physicians that three concussions should negate contact sports. This seems dogmatic. A single serious concussion with prolonged loss of consciousness, altered neurologic findings that were more than transient or prolonged symptoms would seem a greater contraindication to further trauma than several concussions with transient loss of consciousness

or amnesia only. The boys with the "glass jaws," effected by relatively minor blows, cannot safely be allowed heavy contact. It is well to be alerted to a history of headaches in this age group in which frequent or severe headaches not readily explainable are unusual. All bizarre reflexes should be explained before heavy contact, and known epileptics should not participate in heavy contact sports.

Minor muscle group paralysis or atrophy need not necessarily be a deterrent, although it presents a handicap. Muscle mass and tonus is a protection to the skeleton but frequently boys do remarkably well by compensatory muscle re-education. One can be liberal in allowing an athlete with a handicap a trial at a new sport, and the coach or trainer can then be alerted to observe the adequacy with which the handicapped athlete protects himself.

The musculoskeletal system is easily and adequately checked. Let us stand back and look at the athlete as a whole. What is his stature, muscle development, tone, posture and flexibility? The bones in growing boys outstrip the muscles, frequently leaving him with tight muscles, especially in the legs. This results in awkwardness and invites injury. A few words of advice in stretching these muscles may prevent injuries. Previous injuries can be examined for complete healing and return of function as evidenced by range of motion, power and muscle tonus.

The knee, which is the most vulnerable joint and the one most frequently seen with residual disorders, requires special evaluation. Injuries to this joint, if not protected, invite repeated and often more serious injury. Instabilities of the cruciate ligament are checked and compared with the normal knee. This can be adequately done by seeking abnormal motion of the tibia on the femur with the knee flexed and the thigh muscles relaxed. Knees with torn ligaments need at least protective strapping or bracing and, when severe, contraindicate further contact sports. Athletes who have worn braces in college football have been known to discard them when entering the professional ranks. They say that there is less liability to injury to the knee because the bigger men in professional football do not block that low. This constitutes an accepted risk by a mature athlete for compensation, and one not endangering his life. Any instability of the lateral ligament is such a handicap that the athlete realizes his disability. Knees with questionable symptoms or findings referable to the meniscus may be allowed further contact. The activity will invite further difficulty and aid in a diagnosis of sufficient accuracy to warrant surgical intervention. Symptomatic tibial epiphysitis or Osgood-Schlatter's disease requires rest until union of the epiphysis is complete, or until the knee is asymptomatic with graduated exercises.

Any athlete with an injury to a joint must have regained full range of motion and full muscle power if he is to play without additional protection. Compromises in range of motion or muscle power may be made if strapping limits the motion below that range where further injury will occur. Dislocations of the shoulder, for example, can be limited in abduction and external rotation to protect against reinjury adequately. An extremity with good muscle tone is much less vulnerable to injury.

Limited motion of the spine, whether in the cervical, thoracic or lumbar area, usually will limit contact sports because of pain before additional damage results. Persons with symptomatic osteochondritis, spondylolysis or spondylolisthesis should avoid sports involving back strain.

Surgical scars that are well healed after two to six weeks need no further protection. A hernia of small size without danger of incarceration need be no contraindication to active sports. The strain will only increase the speed of its inevitable enlargement. Fractures should show union by physical and x-ray examination with perhaps one exception, those of the transverse processes in the lumbar area in which pain may be the guiding factor. Players with myositis ossificans calcifications resulting from hemorrhage most frequently in the thighs should have regained a full range of muscle motion, and should have protection against additional trauma.

Athletes with mild diabetes with no clinical nephropathy or vascular complications may be allowed full activity. Precautions against insulin reactions resulting from increased exercise should be considered. Healed nephritis with normal urinalysis and blood chemistry need be no deterrent. However, persistent abnormalities negate heavy exercise. Patients with hepatitis or enlarged spleens most frequently following mononucleosis must be with-

held from sports until the organs return to normal, if further damage or ruptured viscera is to be avoided. It has been my experience to see peptic ulcers heal in athletes engaged in active competition when they were doing poorly previously. We have also allowed students with acute idiopathic pericarditis to return to active sports when the disease has completely healed, without further evidence of recurrence or heart damage. Boys with minor personality and psychological problems are frequently benefited by the outlet of sports. However, should competition introduce further frustrations, it must be reduced or eliminated.

The medical supervision of the athlete must not stop with a sport release. Continual re-evaluation of illnesses and injuries should be maintained through cooperation of the coaches, trainers and medical consultants. The necessary liaison is best stimulated by the knowledge that the doctor is genuinely interested in sports and in the athlete's return to the field or floor at the earliest safe time.

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About People, Not Injuries

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"A GREAT deal has been written about injuries, but little or nothing has been said about the recipients of the injury." Admittedly, it is a person who gets hurt and who is treated, not a knee or a shoulder or an ankle. What are these boys (and girls, too), these adolescents, these athletes like? What characteristics or needs (not their knees or their ankles) should we take into consideration when treating them? Are they really different from small children or adults? Do we really need to think of such matters? We do, and we also need to think about ourselves (the doctors who treat them), and about their coaches.

It is axiomatic that doctors primarily treat people, not diseases or injuries. To do this they must understand their patients as well as their patients' ailments. It is also true that adolescents are different, "not yet old enough for a man, nor young enough for a boy; as a squash is before 'tis a peascod, or a codling when 'tis almost an apple"; at this transition period they feel and think and behave differently than at other times of their lives. If their doctor is to be of the most help to them, and they the least trouble to him, he must attempt to understand them, the ways in which they feel and think, and the ways in which they differ from younger and older people. Fortunately, neither these young people themselves, nor the understanding of them, is as difficult or mysterious as those who perennially fear the worst would have us believe. There is no need to study involved psychological theories in order to treat them, but admittedly the more one knows about a few of the characteristics and needs of any age group, the more likely one is instinctively to do or say the right thing. To treat patients as people, not as interesting conditions of the knee or back or shoulder, yields doctor and patient countless dividends.

One characteristic of adolescents which should be understood, always remembered and frequently utilized is their overconcern with themselves. Charmed and preoccupied with themselves, they ignore those who ignore them and usually accept those who respect and show an interest in them. This can annoy a busy adult, but he will save time and gain satisfaction if he will yield to it whenever possible. See them alone, give them a chance to talk, do not interrupt, be (do not just seem) interested in them.

"All he was interested in was my wrist. He didn't pay any attention to me, he was fiddling with it and talking to my mother; so why should I tell him about my back (and anyway she was there), if I had said anything in front of her, she would harp on it forever . . . well, I know you didn't ask me—I just thought you'd be interested." Because that doctor did not see this fifteen year old boy alone, and because he divided his attention between the boy's wrist and his mother, another physician treated the boy and his back. Achieving cooperation, getting these patients to talk, depends on little more than making respect for them obvious, and providing the sort of setting in which any of us is more likely to tell what is on his mind and more likely to respond to another's interest. It is just as simple as that but in dealing with adolescents, nothing is more important.

"Now your knee will be all right if you will just take it easy." "Well, nothing strenuous, maybe track would be all right." "I guess it is strong enough now, try it out." These are commonplace remarks which should be much more specific when directed to an adolescent. Theirs are the years of strenuous living; taking it easy is not in their tradition. Track will be interpreted as the adolescent wishes; obviously it

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can be the pole vault, the broad jump, the dash, the javelin throw, each of which varies considerably from the other in the stress it may put on his back, knee, quadriceps or shoulder. "Guessing" it is strong enough is likely to constitute an underestimation of the stress an adolescent will put on his injured part; he does not have the caution and moderation of an adult. This should be remembered. They use sports (unwittingly) as an outlet for those drives and aggressions which can be expressed in athletics in a socially acceptable way. They use sports to prove their masculinity (which they doubt at times during these years); they use them to gain popularity and recognition from their contemporaries and thus these adolescents go at things hard, to win, in an all-out fashion.

All we can do is to recognize these facts and to remember that we are not dealing with a child who plays in a sandbox or with an adult who, if ever, too rarely exercises. The recommendations and limits must be carefully spelled out and considerable thought given to the adolescent's fitness to withstand the degree of stress to which he is likely later to expose himself. Remembering this, his joint should be stronger than it was before its injury if it is not again to be damaged under similar circumstances.

Concurrently, as we keep in mind young people's habits of living strenuously and going at things hard and recklessly, and therefore their likelihood of reinjury, we must also remember the inappropriateness and undesirability of any but really necessary restrictions. Many adolescents must have strenuous activities to sustain them in the face of academic mediocrity and provide the respite that keeps many of them going. These activities provide them with a group to which they can belong and whose support they temporarily require during those years when they are breaking away from their parents and trying to stand alone. They yield success and acceptance, so badly needed at this time of life when self-confidence requires support.

Such a hasty remark at the time of injury as "you're through for the season" will certainly be withheld when the doctor remembers how important athletics can be to some of these young people. Obviously it is also ill advised from the standpoint of these young people's great capacity for change and for more rapid recovery than older people, but primarily we must realize how much this game may mean to the young person's development. This is not to say that the knee or back does not need consideration too, but a game is often much more to a boy than the game it seems only to be. To drown the boy in the cold water of such an inept remark, or to let a prejudice against some game or games overshadow their value to this boy, or inadvertently to furnish support to an overprotective mother's plaintive "He can't play again, can he, Doctor?" is to forget the needs this particular adolescent may have. He may, of course, never play again but there will be a better time and place for telling him. Later, when one knows the boy and his injury much better, both can be given thoughtful consideration. Most of these adolescents can be strengthened, a much better philosophy and technic than rest and restriction, so that they can play again [*1*]. At all events, until one has had an opportunity to know the boy, it is well to make clear that one's primary purpose is his rapid and complete recovery, that one wants him to get back to his activities. Subsequently it will be clear what the game or activity means to the boy and how much it is really contributing to his development.

For some boys an injury may be a blessed relief. These boys, too, require understanding.

Adolescence is a time of rebellion, a reaction against authoritarianism. During these years the adolescent attempts to modify his childhood conscience, and he often finds this difficult. Adolescents are breaking the ties of home, yet lack the confidence in themselves which would permit them to do so easily and gracefully even were their parents less loath to see it happen. So many try to make this break easier for themselves by denying the value of parental opinions and advice (and of other adults who have authority). None of this makes it easy for the doctor who wants them to follow his orders, and unless he gives their temporary attitudes some thought, broken appointments and broken casts at least can result.

It is not authority that these adolescents resent, it is authoritarianism. Insecure, they even welcome the support which true authority can give them. This, however, comes best from an "outsider" and from someone who clearly is "on their side." What they resent, and will battle in an active or passive fashion, is an atmosphere or remark even faintly reminiscent

of a harrassed or insecure parent's or teacher's "I don't care what you think—my telling you is reason enough." This is just the opposite of an effective technic. This is not to say that adolescents should be handled with kid gloves, that one should not be firm, that one should debate with them or let them make the decisions, or that one should be "pals." They want someone to run the show, someone who has confidence in himself and who obviously knows what he is doing. The overly friendly approach (for obvious reasons) makes many of them anxious; these requirements can be better filled by their contemporaries. These boys do not want to be pushed around; they do want to believe that their feelings are being taken into consideration.

The best answer to all this, in addition to the doctor's competence, is to make clear to the patient that you are his doctor. You are interested in him, not only in his knee and what his parents or coach have been saying; see him alone and give him your undivided attention—"Now tell me about this, what's the story?" Then, as you examine his knee, ask about his school, his team, his other interests, his plans. If the injury is severe, such chitchat is obviously inappropriate. The adolescent's concern for his body is great, and at such a time the less said and the more swift and sure the treatment, the better. Your interest in the injury will then need to be supplemented by little more than a reassuring "We'll take care of things, young man" to show that you know how much this can mean to him.

Making it clear that you are on his side does not mean that your decisions will only reflect his desires. It means no more than that you are his doctor and that you will listen to what he has to say. When his feelings and hopes are bottled up, his cooperation is unlikely; when they are expressed (although you may have to disagree with or thwart his plans), he will probably be amenable. That you are his doctor is made clear from the first minute; from the moment he first sees you, he sizes you up as thoroughly and perhaps as astutely as you evaluate him. Thus do not keep him waiting while someone else tries to keep your attention and tell you his story. Your desire to see quickly what the injury looks like can be a polite means of getting the boy alone. Later, a discussion of your findings, of how things are likely to work out, and your evident interest in getting him back to his activities, ought to be enough to dispel his fear that here is another adult who does not think he is old enough to understand, to have any sensible questions, or to have any plans of his own. With this sort of start, the doctor may find himself (without spending any extra time), healing and helping much more than the injury, and the patient should not need to ignore orders or do anything foolhardy in order to reassure himself that he is not being pushed around or not being masculine.

The athletic injury acquired in team sport is usually of much more importance to the adolescent than any of the other complaints which bring him to a doctor. Many of the latter are of more concern to his parents, and he seeks help reluctantly and only at their insistence. However, if he is on a team, the football knee, the tennis elbow, or the pole vault back are matters with which he wants help, and consequently his doctor is off to a better start. In fact under such circumstances the doctor is often given an unusual opportunity to accomplish many things which other adults have been unable to. Given half a chance, the athlete will accept the physician's friendliness as well as his skill. It is difficult to believe that anything which will help a young person become a better adult is not the doctor's business although he happens to be expert in some specialty.

"Over-training" is an athlete's ailment which is the bugbear of coaches; its avoidance can be an important factor in the prevention of injuries and in the convalescent care of an injured athlete. Over-training can affect an individual and can also spread through an entire squad. Basically it is a mental weariness [3], a state of being "fed-up," and "sick of it all." Usually it develops late in an athletic season and in an athlete who has been doing very well and is striving for just a bit more perfection, a little higher peak which seems to become increasingly unattainable. If unrecognized by the coach, trainer or doctor, this state of mind is likely to result in injury; if not given a day or two off, the able athlete will escape in mind if not in body, and the usual results of inattention will follow. Not trying hard, not intently thinking about his game, eyes wandering to the grandstand, mind drifting off to last summer's dance, the athlete's next recollection is apt to be the referee's whistle and then "What hit me, Doc?"

A good competitor is usually the adolescent

who has learned how to express his aggression effectively, smoothly, not by fits and starts, and in a reasonably controlled fashion. He can let himself go. The poor athlete, or better the one who is unpredictable or who has very good and then very bad days, or who has never lived up to his promise, is on the other hand the one who is bottled up, who has such poor control of his feelings that he fears to let himself go. He is the "nice" competitor; he likes a friendly atmosphere, and may be but little upset by failure, and he can exasperate a coach. In contrast a good competitor may become morose when he loses; friendly on the street corner, on the playing field his opponent is his enemy and he really lets this game be an outlet for his aggression [2]. One very successful baseball player who seemed to have a savage hatred of pitchers has been quoted as saying, "When I face him I keep thinking 'he's trying to take the bread out of my mouth.'"

Whether or not such feelings are good or bad, or do or do not indicate a need for psychotherapy, is beside the point. The facts are that they exist and that competition results in varying responses from different kinds of people. Wedge [4] in commenting on college students has said, "Varsity athletes are less likely to consult us [psychiatrists] possibly because they have less difficulty but more probably because they tend to solve problems by action rather than by contemplation and self-observation." To take athletics away from one person (without furnishing a suitable substitute outlet) may result in unfortunate behavior, but athletics taken away from another may result in relief or no apparent change. Not all athletes want their injuries to heal quickly; some seem to court disaster and then welcome it when it comes. These patients need their doctors' help as much as their injuries do or as much as those who cannot wait to get back into the game; a few others, formerly good competitors, may have new and more mature interests into which they would like to channel their drives and energy but hesitate to do so. The doctor who has cared for their previous bruises is in a strategic position at this time to help them with the important conflicts which often arise out of such situations.

Although girls have fewer injuries than boys, they too when injured may require a good deal of understanding. At this time of their lives they do not have the strong sexual drive which boys have and the consequent need to channel their aggressions in socially acceptable ways; they do, however, have the same degree of self-concern, the problems which grow out of their changing feelings toward each parent, a need to acquire independence, and what is for a few a considerable problem associated with the business of becoming more feminine.

To many girls athletics are no more than pleasant recreation, and skill in them important not for the success and prestige it can bring but rather as a social asset and as another way of meeting boys. Admittedly this is no minor matter but only now and then are athletics as important to girls as to many boys; however, they can be, and it is important to understand those girls to whom athletics mean so much. The girl whose feelings have never progressed beyond the stage at which she began to adore her father and wanted only to please and be like him, and who therefore planned for a career in athletics like his, can be very upset by an injury which threatens to change all this. For such a girl, "you'll never ski again—it's lucky you aren't a boy" could not be more inappropriate.

Tomboys can be similarly upset when an injury threatens to shut off the avenue of interest and recreation chosen through fear of other activities and thoughts that are more feminine. Not yet ready to accept femininity, but not wanting to withdraw from the world, they keep busy as do the boys they would still like to be. Admittedly, it would be well for them to give up baseball or to find other friends than horses, but the injury that may keep them from either is hardly to be described as "a blessing in disguise" at the time it occurs. Later, if such a remark has been avoided, an understanding doctor may, without knowing he has been responsible for it, see his interest in the patient stimulate her desire to become more feminine. Although this may indeed be unconscious psychotherapy on his part, the result is nevertheless all to the good. It is really an extra dividend from showing an interest in a patient, from understanding what may be happening, and from instinctively employing those most valuable tools, silence and kindliness.

Those who pretend to know all the answers about adolescents, or about any group of people for that matter, display ignorance.

However, to regard adolescents as problems or their ways as mysterious and beyond understanding, has no justification in fact. There is no excuse for focusing on the ailment and ignoring the person. These are people, not problems. At times, adolescents may be unpredictable but most of the time they are just young people trying to grow up and by and large doing a good job of it, not needing or wanting much help. However, if we remember some of the things that bother them, we may be in a position now and then to give them a "leg up" when the going is rough; at least we should be able to avoid making their problems more difficult for them to solve. This we can do if we will only avoid forgetting momentarily that it is somebody, not some part of a body, that we are treating. After all, hope, thoughtfulness and understanding have been irreplaceable therapeutic agents for hundreds of years.

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The Place of the Trainer in Modern Athletics

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THE background of athletic training is long and illustrious. It had its start with the ancient Greek and Roman athletic contests, as evidenced in our archeological museums. Artists of the time found much of their inspiration in scenes on the gymnasium, palestra, track and field. Vases, our most important record, reflect the various phases of the life of the athlete. Bronze and marble sculptures, gems and coins also add to our knowledge. There are many instances recorded on these vases of the aryballos (oil flask), strigil (instrument for removing oil and dust from the body after exercise) and sponges [*1*]. Other specific scenes shown on vases include an attendant drawing a thorn from an athlete's foot [*2*] and two scenes entitled "Wrestlers with their trainer in the palestra." (Fig. 1.) Another, perhaps the first recorded instance of a trainer instructing the principles of fair play, is entitled "Trainer beating with his stick a youth who is gouging his opponent's eye" [*4*].

From the time the ancient Greeks pitched their tents on the plains of the Elis in the dim centuries of the past and brought together the young men of their land in the first of all Olympic games, until their modern revival in 1896 and down through recent times, the trainer has been an important factor in keeping the athlete in condition for top performance.

Through the years the duties and qualifications of the trainers have changed in the same manner that the three R's of "reading, 'riting and 'rithmetic" have changed to the present "rockets, radiation, and rock and roll." The crude methods of the old-time trainers have become a thing of the past. The day of "the rubber," the know-it-all jack-of-all-trades and master of none, is over. Following World War I the athletic trainer as a specialist in the prevention of injury made his appearance in intercollegiate athletics. It was at this time, 1917, that Dr. S. E. Bilik published the first text devoted exclusively to athletic training and the treatment of athletic injuries [*5,6*]. Other excellent publications have appeared since [*7–10*].

The trainer today must have a sound understanding of the human body and be a keen and unbiased observer of the body in action. He must know a good deal about physiology, kinesiology, psychology, hygiene, massage, conditioning, therapeutic exercise, diet and the various modalities of physical therapy. In addition, he is the father confessor of the squad.

In a recent study "Red" Burnett, Trainer at Utah State University [*11*], found that very little research had been done on the history and background of athletic training. He further stated that there were many books and pamphlets on training methods but none elaborated on the duties of the trainer or what his qualifications should be. I am happy to report that steps have been taken to remedy this situation by the National Athletic Trainers Association (N.A.T.A.) [*12*].

This organization was founded in Kansas City, Missouri, on June 24, 1950. Its objectives are:

1. To advance, encourage and improve the athletic training profession in all its phases and to promote a better working relationship among those persons interested in the problems of training.

2. To develop further the ability of each of its members.

3. To better serve the common interest of its members by providing means for a free exchange of ideas within the profession.

4. To enable members to become better acquainted personally through casual good fellowship.

At the present time there are six classes of membership: active, associate, allied, advisory,

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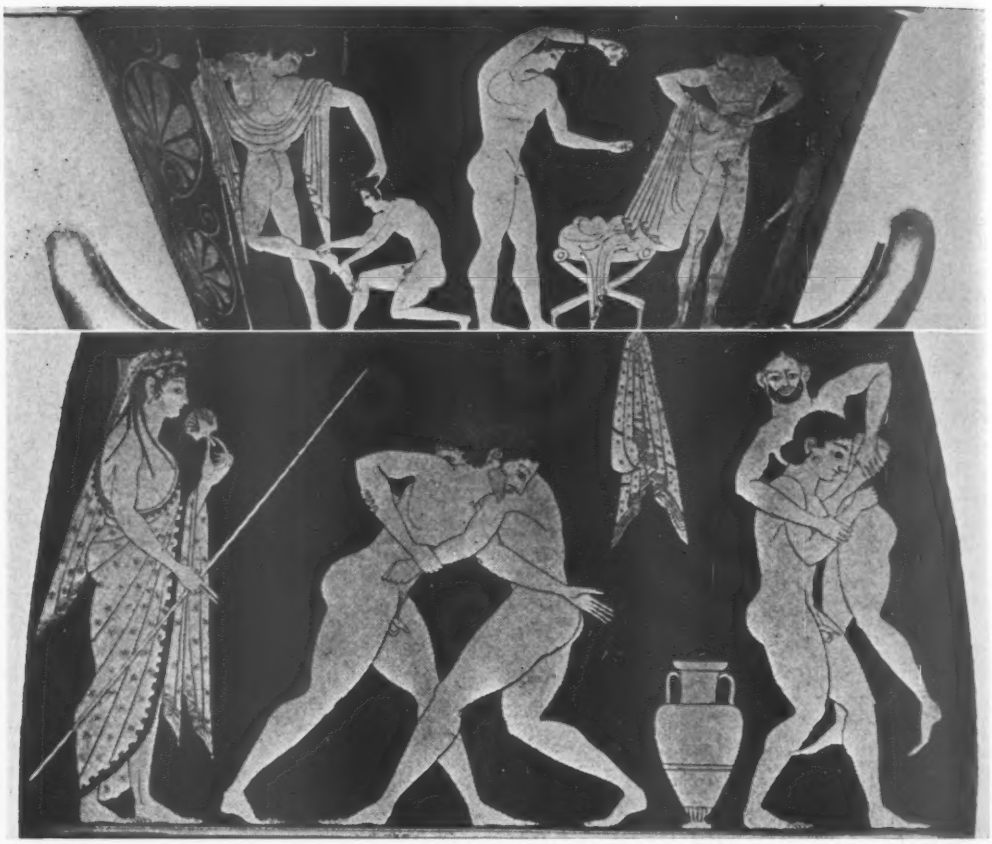

FIG. 1. Trainers of ancient Greece as depicted on amphora in the Altes Museum, Berlin. Above, a trainer examines the foot of an athlete while another pours oil on his hand for massage. Below, a trainer, holding a flower to his nose, supervises wrestling.

honorary and retired. As of June, 1958, there was a total membership of 598. Authority and responsibility for the association is vested in nine directors who represent geographical districts of the United States or athletic conferences previously organized. One of the district directors is annually selected as chairman of the board. This year Mr. A. C. Gwynne, Trainer at West Virginia University holds this office.

Since 1950 the N.A.T.A. has held an annual meeting in June of each year. They have all been well attended, and have featured as speakers outstanding medical, surgical and orthopedic specialists in addition to trainers from all sections of the United States. Warm approval of the aims and purposes of the association has been forthcoming from many leaders in various fields of medicine.

In June, 1955, at Boston, the Board of Directors of the N.A.T.A. appointed a Committee on Professional Advancement consisting of thirteen athletic trainers and five medical advisers (Drs. R. G. Brashear, J. S. Feurig, D. H. O'Donoghue, W. D. Paul and E. T. Price). The committee was instructed to devote itself to a thorough investigation of athletic training in all its phases and to develop an educational curriculum that would be acceptable to the colleges and universities of the nation. This committee, after three years of study, presented a proposed curriculum to the membership at large for comment in 1958. This included: (1) a curriculum that would give the

individual the broadest teaching certificate possible; (2) a curriculum of pre-physical therapy courses that would be accepted by any American Medical Association–approved physical therapy school; (3) a curriculum to prepare men in the management and prevention of athletic injuries. At the present time, only one institution in the United States, the University of Indiana, is offering a bachelor of science degree in athletic training. No doubt in years to come, if the aforementioned curriculum is accepted, the standards of future trainers will be raised. This committee is also exploring the possibility of formal alliance of the N.A.T.A. with the medical profession.

In September, 1956, the N.A.T.A. started publishing its own quarterly journal, covering new methods, recent developments and other matters pertinent to training and of interest to trainers.

In 1957 the N.A.T.A. became an affiliated member of the National Collegiate Athletic Association and a Group "E" member of the United States Olympic Committee.

In addition to the N.A.T.A., each of the nine regional trainers associations are self-governing through their own specific constitutions and bylaws. In their relation with the national organization, regional associations are under the jurisdiction of the N.A.T.A. constitution and bylaws.

In 1957 the Council of the National Collegiate Athletic Association authorized the appointment of a Committee on Sports Injuries and Saftey. The purposes of this committee are:

1. To collect and develop pertinent information regarding the prevention and treatment of sports injuries and the utilization of sound safety measures at the college level.

2. To disseminate such information as might be appropriately brought to the attention of the member institutions of the N.C.A.A.

3. To recommend the establishment of policies and standards by N.C.A.A. rules and tournament committees, or the Association as a whole, designed to better the safety factor in college athletics.

This committee is composed of the following members: Carl S. Blyth, Director of the Applied Physiology Laboratory, University of North Carolina; Jack C. Curtis, Head Football Coach, Stanford University; Arthur S. Daniels, Dean of the School of Physical Education, University of Indiana; Ernest B. McCoy, (Chairman), Director of Athletics, Pennsylvania State University; Kenneth B. Rawlinson, Head Trainer, University of Oklahoma; and Dr. Allan J. Ryan, A. M. A. representative, Meriden, Connecticut.

To date, this committee has completed the following surveys: (1) A study of injuries to the head, face, shoulder, neck, pelvis, knee and ankle that were serious enough to necessitate a boy missing a practice session or making it necessary to alter his daily practice routine. (2) A listing of standards for equipping and maintaining a training room for the prevention, treatment and rehabilitation of athletic injuries. Both surveys were conducted by various trainers in the United States. Thus athletic trainers in the United States, through organization, establishment of standards and participation in a program of inquiry, are achieving the status of a true paramedical profession.

The daily activities of the trainer are principally concerned with prevention of injury, treatment under medical direction and rehabilitation.

Prevention begins with arrangements for thorough physical examinations of all players, and surveys of dressing rooms, shower rooms, playing fields and equipment to eliminate all possible hazards. Most trainers spend more time on prevention of injuries than is commonly believed by the average layman or even by most school officials. It should be emphasized that treatment is only part of the trainer's duties and probably a less important part. The more injuries that can be prevented, the fewer there will be to treat and rehabilitate. Since an injured athlete is of no value to his team, his coach or to himself from an athletic standpoint, the greatest concern must be with prevention of the injury which causes him disability. Conditioning is all-important. Bob Shelton of the University of Illinois, in an address before the Illinois Association for Health, Physical Education and Recreation, made the following statement, "Conditioning is more important than skill, because conditioning helps prevent injuries and the best halfback in the world is of no value sitting on the bench."

At the University of Oklahoma conditioning for the fall football season begins at the close of spring practice (approximately the middle of April). The major portion of the program must be carried on by the athlete himself. He cannot be expected to do this without proper direction

and instruction. Each player is given a set of exercises which he is asked to do at least three or four times a week until the first of August and daily thereafter until fall practice begins. He is encouraged to supplement these exercises by jogging, distance running, wind sprints, etc. He is urged to get plenty of rest, sleep and good foods, and to avoid dissipation throughout the summer months. Furthermore, each boy is assigned the weight at which he is expected to report for the first day of fall practice. It is our firm conviction that if the athletes have the desire to be great, they must be willing to pay the price to help accomplish their goal.

No team is any better than the physical condition of its players. Red Sanders, the late Head Football Coach at the University of California at Los Angeles, once made the statement that football is 40 per cent ability and 60 per cent physical condition and mental attitude. Tom Harmon, former Michigan All-American football player and presently a sportscaster, went Red one better when he stated that football these days is 90 per cent mental and physical preparation. It all boils down to the axiom that no team is better than its physical condition. The primary objective must be to get the team, as a whole and as individuals, physically stronger and tougher than the "opponents." One must impress on players that many fail to make the team for no other reason than they are unwilling to pay the price to get themselves into tiptop physical condition.

A second phase of prevention is good equipment. This is an absolute necessity for a sound program. Of course, many schools have a limited budget with which to work and this of necessity handicaps them in the purchasing of quantities of equipment. Although the budget is limited, one would warn against the purchasing of large quantities of second-rate equipment because by this means none of the players is properly protected. It is recommended instead that schools purchase the best even though the supply may be limited. Too much emphasis cannot be placed on proper headgear. The modern, lightweight headgear is effective but does little good if the suspension apparatus is not properly placed to keep the head from contact with the inside of the headgear. Once good equipment is supplied, the trainer and coach should insist that in order to compete the players wear the equipment which has been prepared for them. Rushing into a contest without properly placed and fitted gear is to be condemned.

Furthermore, at least a weekly check of each player's equipment should be made by the trainer or some other responsible person. Is the suspension in the headgear too loose? Are shoulder pads or hip pads broken? Are the pants too large so that the thigh pads are sliding? How are the shoe cleats? A single loose suspension string in the headgear can mean a severe concussion. The slipping of a thigh pad may result in a contusion (charleyhorse) which can keep a player inactive for the rest of the season.

It is necessary in fielding a present day football team to do a good deal of protective taping. Every trainer, doctor and coach has his own method but whatever the technic the following principles should apply:

Rules for applying bandage: (1) Be neat, clean and thorough. (2) Use the simplest method of application to accomplish the desired result. (3) Start the bandage with the limb placed in the position in which it is to remain throughout the wrapping. (4) Anchor the bandage well, preferably at an angle to the wrap. (5) Start at the lower part of the limb and bandage toward the body. (6) Bandage snugly but not tight enough to be constrictive.

Rules for applying adhesive tape: (1) Shave the part carefully and apply benzoin or some similar material to the skin. (2) Select the size of tape that best fits the contour of the body. (3) Basket weave the tape for additional strength at stress lines. (4) Tape directly from the roll. (5) Be sure the tape is applied smoothly with no wrinkles to cause blistering of the skin beneath. (6) For the best support, tape directly to the skin rather than over gauze or socks. (7) Avoid constrictive circular taping. (8) Replace the tape frequently. Do not leave it on for more than a few days at a time.

At Oklahoma [*13*], as at most other colleges and universities, every member of the football squad must have his ankles either taped or wrapped before each practice session or game. Previous injury is an indication for taping. Other joints are protected as indicated after analysis of each case by the team doctor.

The wrap used for the ankle is the "Louisiana" wrap. (Fig. 2.) This is almost identical with the Harvard wrap. Both include a turn about the heel which limits lateral motion without appreciable interference with flexion and

extension. Such wrapping is very effective. Quigley, Cox and Murphy [*14*] report that at Harvard no complete rupture of the ankle ligament occurred in fifteen years' routine use of ankle wraps. Hanley of Bowdoin College stated "We have not lost a man for five years who has worn his ankle wraps correctly" [*15*].

Many times during the season it is necessary to improvise special equipment to protect a specific injury. A fracture glove may be necessary to protect an injury to the hand, a pair of oversized shoulder pads to cover a weak or bruised shoulder, or a pair of special hip pads to protect a contused iliac crest. Every trainer of experience will have his own particular solution to these problems.

After injury has occurred the trainer must work hand in hand with the team physician. They should function as a team with the same set of rules and signals and the same objective—the complete rehabilitation of the player. It must be kept in mind that there are several conditions which make the treatment of the athlete quite different from that of the ordinary patient. Dr. E. T. Smith of Houston, Texas, lists these as: (1) He is, or should be, strong and in excellent physical condition. (2) He is young, and his healing and recuperative power is above average. (3) He has an incentive to get well, will cooperate to the fullest extent and will tolerate early rehabilitative procedures. Because of these factors it is usually possible to get an athlete back into competition in a much shorter period than an average working man will feel able to return to his job.

Rehabilitative exercises should be started as soon as possible after an injury. In fact, it is advisable to continue exercising other portions of the body even though the injured part must of necessity be immobilized. It is much better to prevent atrophy than to relieve it. Obviously some exercises will be more suitable than others for a specific situation, and they must all be proportioned to the degree of disability of the individual player and gradually increased as he improves. It should be emphasized again that the player as a whole should be treated, not simply the injured part. It is the unusual injury which will not permit active exercise of other parts of the body from the first day.

A related problem with which the trainer, coach or team physician is confronted is the player who is afraid of injury. It is necessary to convince him that if he gets himself in the proper condition he will not be subject to injury.

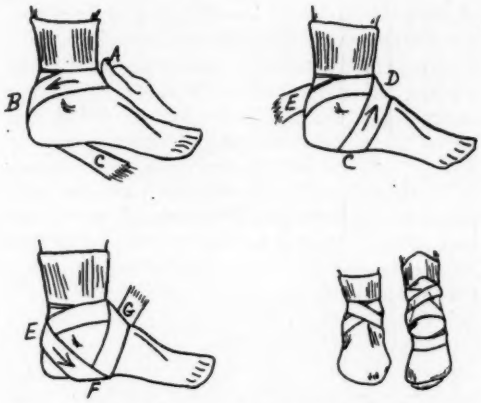

FIG. 2. The Louisiana wrap requires a 100 inch web ankle wrap. (1) The start (A) of the wrap, crossing the top of the ankle above the lateral malleolus (B), around under the heel from the inner side (C). (2) The wrap crosses the dorsum of the foot (D) around the inner side of the ankle above the internal malleolus (E). (3) The wrap crosses the outside of the heel under the plantar surface of the foot (F) to terminate at (G) the starting point. The wrap then continues until the bandage is exhausted with suitable overlapping of the turns so that one turn is not directly superimposed over the one beneath it. This application should be made snugly but not tight enough to interfere with circulation. It may be made over a heavy sock, care being taken to avoid wrinkles. A little practice will determine the degree of tension necessary. (From the publications of the Cramer Chemical Company.)

The trainer is in a unique position to build confidence by convincing the player that if he is in top physical condition, uses his equipment properly, follows the coach's instructions precisely, and plays with "carefree abandon" and no hesitation it is very unlikely that he will be hurt.

If confidence cannot be instilled and he remains "gun shy," he should be advised to drop out of the sport in the interest of his own safety.

It is encouraging to note that there are fewer serious injuries every year. Dr. Floyd R. Eastwood reported to the American Football Coaches Association in January, 1958 [*16*] that sixteen players had died during the past football season (1957)—thirteen in high school games, two in sandlot, one in semi-pro and none in college. This is indeed deplorable. However, it should be noted that this is a decrease from the annual average of 17.38 deaths since the yearly surveys began in 1931, and that

there were no deaths in colleges or universities. He further stated that for each football fatality a comparison with other known accident information shows football to be much safer than other activities. For example, the ratios are: 236.5 deaths by motor vehicles to one in football; 337 deaths from drowning accidents to one in football; and 241 deaths from firearm accidents to one in football. This improvement can be explained in part by the fact that there are more qualified men in the field of conditioning, that better equipment has been designed and is being used, and that everyone is becoming increasingly concerned about the prevention of injuries. It has been said that in the past coaches were concerned about getting a team on the field, but now they are vitally interested in keeping a team on the field. An adequate training program is one of the best means to accomplish this end.

In conclusion, there is no doubt that the trainer has come a long way in recent years. Today he is an important factor in the running of a college or school athletic program.

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Athletics and Nutrition

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WHAT constitutes the "optimum" diet for athletes training for competitive contests is a perennial question. For centuries trainers and coaches have advocated special dietary schemes, stemming from older traditions and superstitions, and based on the belief that the ingestion of particular foods would augment the physical capacity or efficiency of the performer.

One of the most widespread of such practices has been the advocacy of ingesting large quantities of meat meant to replenish "muscular substance" following the "losses" supposedly incurred during severe muscular work. This particular practice was first recorded in Greece during the fifth century B.C., and ascribed to two athletes who had deviated from the hitherto traditional (chiefly vegetarian) diet of the time to a regimen entailing the intake of large quantities of meat which lead to increased body bulk and weight. The fifth century also saw a change in the cultural outlook on physical fitness: instead of being considered essentially a broad prerequisite for participation in the defense of the country, physical fitness became subordinate to training for specific sports, excellence in which became superior to almost all other values [*21*].

An attitude of this sort has not disappeared among the athletes specializing in particular sports. In sports, such as boxing and wrestling, present day athletes, professional and amateur (and, among the latter, even high school students), not infrequently place themselves on such stringent regimens as "crash diets" combined with dehydration so as to lose weight. This regimen causes rapid weight loss and the athlete can thus make lower weight classifications. While it may be desirable for an overweight person to lose weight, a crash diet is not the method to be recommended. More often the intention of those athletes is not to attain their most "desirable" weight for competition, but rather to compete with advantage against those who really do belong in a lower weight bracket. When such weight classifications have been set up to provide competition on an equitable basis, the violation of these standards by sudden self-inflicted starvation and by temporary dehydration serves no more the ethics of sportsmanship than it does the health of the people concerned. Such practices have recently been condemned by the A. M. A. [*18*].

TYPES OF PERFORMANCE IN RELATION TO NUTRITION AND DIFFICULTIES ENCOUNTERED

Forgetting such tricks as crash diets, there are more important features of nutrition in relation to the level of physical performance which have been objects of experimental study during the past sixty years. Since muscular performance includes forms of work other than athletics, experimental evidence gathered from industrial output studies, or from laboratory tests, may be applicable to performance of athletes. Causeret has pointed out in a recent review [*10*] that consideration of the relation of nutrition to athletic performance entails examination of (1) additional needs imposed by the type or amount of activity performed, (2) the nutritional status of the participant at the outset of performance, and (3) the effect

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supplementation of the diet may have on performance. It is extremely difficult to evaluate the effect of a single food component on physical performance because of the interference of such variables as motivation, differences in experimental conditions, types of work performed, and the wide range of individual response. Not infrequently a special value has been attributed to a particular nutrient while in fact, the observed effects were due to psychological factors in motivation or to progressive training.

The importance of well designed and well controlled experiments is thus particularly important in this field. Perhaps one advantage of carrying out experiments directly on enthusiastic athletes is that they are constantly training to better their previous performance, exerting an intense effort on each occasion, and thus, to a certain extent, minimizing variations in motivation. However, since most of the data on nutritional needs of athletes have of necessity been obtained from laboratory studies rather than on the athletic field, these data may reflect an unnatural setting for performance and thus may not be directly applicable to athletic contests.

A possible factor in the nutritional needs of the athlete is the difference in physiological demands imposed upon the body by different types of exertion. The type of stress imposed by a tennis match is quite different from that entailed by a single effort field event in track. It may be useful to classify athletic events according to the intensity of energy expenditure and to duration into (1) single efforts, in field events such as the high jump or javelin throw; (2) sprints and hurdle races; (3) middle-distance runs, such as the mile run; and (4) prolonged efforts taking more than one hour, such as the marathon [*19,56*]. The physiological demands developing from short intense efforts and the nature of the resulting fatigue are different from those for long duration events. It is therefore possible *a priori* that the nutritional requirements for optimum performance may also differ for different types of sport.

CALORIC COST OF MUSCULAR WORK

The first nutritional requirement in athletic performance is the caloric cost of the type of activity considered. Passmore and Durnin [*46*] have reviewed light respirometer determinations of the relative caloric cost of sports. These estimates of actual energy expenditure are a necessary element in the over-all planning of required caloric intakes. Depending upon the intensity and duration of the daily exercise of the athlete, his over-all calorie requirement might range from 3,000 calories to as high as 6,000 calories. For example, an average cost of playing volleyball is 3.5 calories per minute; that of tennis, 7.1 calories per minute; of cross country running, 10.6 calories per minute; and that of swimming the crawl at 55 yards per minute, 14.0 calories per minute. If the energy expenditure from the activity is superimposed upon that for daily maintenance of the body and other light activities (also reviewed by Passmore and Durnin) the possibility of the wide range cited becomes apparent.

ASSESSMENT OF OPTIMUM WEIGHT

While a physically active person can rely upon his appetite as a guide to securing an intake of calories adequate to meet expenditures, a preliminary assessment of his fat reserves prior to training may indicate a need for gaining or losing weight. Since the energy cost of activity is proportional to body weight in most athletic events [*20,35*], an overweight person expends more energy and burns more of his body reserves to accomplish the same amount of work than he would if he were at his "desirable" weight [*44*]. It is one of the ironies of modern athletics that there are certain specialized sports in which a degree of overweight is useful or at least not detrimental. However, for most forms of activity the overweight person will be at a disadvantage for optimum performance, and therefore needs some degree of caloric restriction over a period of time. In younger athletes, particularly those of high school age, normal increments in weight should be expected for growth, and increased caloric allowances should be made accordingly.

To determine the desirable weight for a given athlete the best guide is the composition of his body, rather than the standard height–weight–age tables which too often lead to misinterpretation. Athletes are often misclassified by such tables because of the high proportion of muscular content in their total body composition. Welham and Behnke [*3,59*] measured the body density of twenty-five professional athletes, of whom seventeen were "overweight" according to the standard height–weight tables. They found that eleven of the seventeen had

increased lean body masses as measured by specific gravity determinations. In other words, although they were "overweight" according to the tables, they were in fact "underfat." Besides gravimetric determinations, the use of skinfold measurements of subcutaneous fat with special calipers also gives a more accurate picture of the actual fatness of an athlete than the height–weight tables. If such procedures are used at the beginning of a season for assessing the nutritional status of the individual provisions can be made for planning the appropriate caloric intake.

FUELS FOR MUSCULAR WORK

Further consideration of the cost of muscular work leads to an analysis of sources of energy to fulfill the different demands imposed by the various types of activities. It has been suggested that "changes in diet may affect the amount of energy and the rate at which this can be made available during performance [*19*]." Shorter, more intense field activities which call for maximum momentary effort (such as sprints and short distance swimming events) may rely for the fulfillment of their energy requirements upon available stores of high energy creatine phosphate and adenosine triphosphate, and upon the anaerobic breakdown of glycogen to lactic acid.

In sports in which efforts of longer duration are required, continuous supply of energy becomes essentially dependent upon oxidation processes to replenish high energy phosphate stores. Availability of oxygen and its efficient use can then become the limiting factor in performance. In turn, availability of oxygen is limited by the capabilities of the respiratory and circulatory systems, the general limit being 4 L. of oxygen per minute. By increasing the recovery period after exercise, a person is able to maintain a level of energy output in excess of that supplied by the maximal oxygen intake during the actual exercise. An oxygen debt up to 16 L. may thus be incurred. This debt must be paid back during the recovery phase. The limiting factor here is the level of tolerance of the body to the accumulation of lactic acid produced during anaerobic glycolysis. During recovery, restoring of glycogen and of high energy phosphate takes place at the expense of burning some of the accumulated lactic acid.

For short distance events, the athlete may rely upon the recovery period to pay back the oxygen debt incurred; in intermediate distance events he may rely upon both a steady state and recovery; and in the long distance trials he must maintain a steady state to meet the metabolic needs throughout [*23*]. In the latter case, the energy stores supplied by particular foods as well as the physical efficiency of the individual may be of importance. In terms of efficiency of utilization of oxygen it may be worthy of note that 1 L. of oxygen yields 5 calories if used to burn carbohydrates but only 4.5 and 4.6 calories if used to burn protein and fat, respectively. This is a 10 per cent difference in the use of oxygen and may be an important factor in competitive performances under certain circumstances.

EFFICIENCY OF WORK

The study of patterns of eating and their specific effects (including relative composition, spacing, or omission of meals as well as specific food supplementation) upon the physical performance of manual workers and upon athletes under field or laboratory conditions, involves a complex analysis of the human response in work output. The results of studies in manual workers are difficult to interpret because of the many psychological factors involved in the type of fatigue produced, and the great variety in the type of work performed. In situations in which workers are highly motivated to greater productivity, determination of efficiency may have more meaning. The significance of such results is further enhanced by better control of experimental conditions.

In the laboratory, pulse rate, oxygen consumption and recovery time have been classically measured while work was performed on a bicycle ergometer. Such determinations yield indices for work performance in terms of physical endurance. Other tests, such as those employing hand dynamometers to measure strength or psychomotor tests to measure reaction time, are also useful for evaluation of performance. Biochemical analyses of blood or urine before and after exercise to measure such variables as lactic acid or glucose levels have also been conducted. Because of the variety in the type of measurement as well as in the type of performance, a given person may vary significantly in ability from one test to another even under "controlled" laboratory conditions. This again makes interpretations of results

difficult and applications to athletes of dubious value.

The "gross efficiency" of the performer is calculated from work output studies as the ratio of mechanical work performed to total or gross energy output. "Net efficiency" is the ratio of mechanical work performed to the increase in energy output over some standard baseline such as basal metabolism. Generally, in man the net efficiency is in the vicinity of 25 per cent [23]. The evaluation of the possible effects of specific factors upon the efficiency of the body has to take into account endowment of the individual with respect to coordination, body build, and psychological makeup. Training in itself improves strength, endurance and skill of performance, and increases the physiologic efficiency over that of the untrained state. Taking these factors into consideration, and in spite of the limitations listed herein, such determinations of efficiency are the best experimental basis for the analysis of the possible effect of meal patterns and dietary supplements on performance.

PATTERNS OF EATING AND PERFORMANCE

The influence of spacing meals and the number of meals ingested per day has been studied in relation to its effect upon physical performance. Using a bicycle ergometer, Haggard and Greenberg [24] found that partaking of meals frequently led to higher levels of performance, and they maintained that total work output could be increased by a pattern of five meals taken during the day. In further experiments, conducted in a shoe factory in which three or five meals per day were given, the result was greatly increased productivity for those eating five meals. They also found that the omission of breakfast resulted in greatly inferior production in the morning compared with that in the afternoon. Other investigators [25,28] have been unable to find such increased muscular efficiency in performance tests. In industrial experiments it is difficult to ascribe the beneficial effects of increased productivity to the stimulus of food alone. Psychological effects of a rest period or break from work can likewise result in augmented production [32,49]. Haldi and Wynn [29] could not find a significant increase in the productivity of seamstresses who were given food during mid-morning and mid-afternoon breaks. Neither the kind of food nor the amount, varying from 80 to 650 calories, affected the work output.

In a review on the effects of meal habits on performances, Hutchinson [31] has concluded that frequent, moderate-sized meals may produce a maximum efficiency from the psychological standpoint: long intervals between meals have unfavorable effects. He believes that "with breakfast as a possible exception, the ingestion of food is not followed by any great increase in industrial productivity or improvement in athletic performance."

The effects of omission and composition of breakfast have been studied by Tuttle and coworkers [15,17,53,54,55]. When breakfast was omitted altogether, or black coffee alone was taken, there was an adverse effect on maximum work output as measured on a bicycle ergometer. An increased reaction time and muscle tremor were found as compared with the response after the ingestion of light or heavy breakfasts. Some subjects experienced unpleasant physical effects such as dizziness and nausea when breakfast was omitted. In a study conducted on women, Orent-Keiles and Hallman [45] found that a breakfast consisting of black coffee only produced no rise in blood sugar, and that a gradual decrease took place during the ensuing three-hour period. The subjective symptoms experienced by these subjects were similar to those reported by Tuttle.

Causeret [10] has mentioned a study conducted in South Africa among Moslems who during one period of the year (Ramadan) eat only two meals a day, one early in the morning and the other at 6 P.M.; during the rest of the year three meals a day are eaten. Results of timed races conducted during Ramadan and at other times of the year, indicated better performances during the period in which three meals a day were eaten.

Although experiments of this nature do not show what would happen under conditions of prolonged adaptation to an altered meal pattern, they suggest that athletes should have at least three meals a day or perhaps more frequent, lighter meals. This is particularly indicated if the exercise practiced is of long duration. The last meal preceding athletic contests is usually three to four hours prior to short duration events to allow for more complete digestion of the food. Strong emotions or nervousness felt by the performer prior to or during the contest have less effect upon the

digestive processes if this last meal is eaten well in advance [4,56].

COMPOSITION OF MEALS AND PERFORMANCE

The use of a high proportion of carbohydrate might be expected to produce a decided advantage because of its known value as the preferential source of muscular fuel. Obviously, more fat is metabolized as bodily stores of carbohydrate diminish. As Keys points out, "at any one time, the substances metabolized depend upon the relative availability of substrates, the accumulation of metabolites, the intensity of work, and the amounts of various enzymes present" [34]

Gemmill [22] has classified the type of studies which relate meal composition to performance according to: (1) those in which subjects exercise following the administration of meals of the desired composition, and (2) those in which the subjects are fed a special diet high in the desired component and low in the others for several days to "saturate" the body with one type of food prior to the studies of performance in the basal state.

Among the studies of the first type is that of Haggard and Greenberg [24] in which they attributed a higher degree of efficiency (about 25 per cent above average) in persons fed a high carbohydrate meal. This result has not been duplicated, at least not to this extent by other investigators. Haldi and his associates [26,27] found no evidence of a beneficial effect after the ingestion of a high carbohydrate diet as compared with an isocaloric meal low in carbohydrate on the performance of swimmers in a 100 yard sprint. From this study on swimmers they concluded that the body stores of energy are sufficient for intense exercise of short duration, and that muscular efficiency is not affected by the size or type of meal ingested before exercise.

In studies on the respiratory quotient and muscular efficiency following ingestion of sucrose or glucose, Wrightington [61] reported differences in the respiratory quotients but not in the muscular efficiency as related to either form of sugar.

Although the beneficial effect of sugar ingested prior to performance is not confirmed for light exercise or for short duration intense exercise, carbohydrate stores may actually become a limiting factor in prolonged events, such as long distance cycling, prolonged golfing and marathons. In such instances there is a valid argument for the ingestion of some form of sugar which is readily metabolized by the body. This practice is also in accordance with the fact that a given amount of oxygen consumed gives rise to a 10 per cent higher caloric output when used to burn carbohydrates than when used to burn protein or fat.

In an experiment reported by Christensen and Hansen [13], a subject on a high carbohydrate diet was able to continue strenuous work three times as long as he could on a high fat diet. Working with trained athletes who had been kept on diets (1) extremely high in fat, (2) high in carbohydrates or (3) mixed in content for several days prior to exercise, which was then conducted in the basal state, Christensen and co-workers [14] found that during heavy work, endurance was impaired in patients on the high fat diet while work could be extended much longer in those on the high carbohydrate diet. From determinations of respiratory quotients, the authors concluded that trained athletes utilize both carbohydrate and fat during rest and light work, but an increased percentage of carbohydrates in heavy work if available. They interpreted this as "better utilization of carbohydrate and a higher caloric value of the oxygen utilized for carbohydrate combustion compared with fat combustion." On the basis of their findings they advocated cessation of heavy work the last few days before athletic contests of the prolonged type to provide ample time for the filling of carbohydrate stores.

In similar experiments Krogh and Lindhard [39] compared the efficiency for two extreme types of diets, and found a higher net muscular efficiency in subjects on the high carbohydrate diet. The values they obtained indicated an efficiency on the average 11 per cent greater in subjects on their high carbohydrate diet than in subjects on their high fat diet; similarly Bierring [6] found an 8.3 per cent difference in efficiency. Gemmill [22] has criticized these results because they were results of extrapolation, and concludes that the actual differences in Bierring's study was a 4.5 per cent greater efficiency in subjects on the high carbohydrate diet. Such an increase would still be highly significant in terms of competitive athletics. Other workers [41] have found the average net efficiency in persons on (1) a normal diet, (2) a high carbohydrate diet, and (3) a

high fat diet, to be similar during light work; however, there was a decline in efficiency in persons on a high fat diet following the fourth day of this regimen. These results, in addition to the effect of decreased endurance noted in subjects on the extremely high fat diet, would lead to the conclusion that in the long term diets of athletes better efficiency will be maintained if the proportion of calories derived from fat is not too high. (In the average American diet the percentage of fat is high, generally of the order of 40 per cent of the total caloric intake, and usually higher when the caloric intake is greater.)

While originally protein was thought by Liebig to be the primary source of muscular energy, the work of Voit and Pettenkofer [*47*] refuted this theory. This refutation has been abundantly confirmed since [*11,39*]. While it has been demonstrated that nitrogen excretion does not rise significantly following muscular work [*9,12*] articles frequently appear suggesting a liberal protein intake during training [*52*].

In experiments relating the level of protein intake to the work performance of individuals, Chittenden [*21*] claimed beneficial effects from low protein intakes of 50 to 60 gm. maintained by subjects in training over a period of five months. Although no indications of harmful effects from this level of protein intake were obtained, there were no control subjects to indicate that the gradual improvement in strength observed by Chittenden was due only to reduced protein intake and not to training. Darling and co-workers [*16*] conducted a study on three groups, (1) persons on restricted protein intake of 50 to 55 gm.; (2) persons on a normal diet; and (3) persons on 160 gm. of protein daily over a period of two months. Their results indicated no harmful or beneficial effects from either the low or high protein intake upon the efficiency or health of the men engaging in hard manual work.

Although the concern of most investigators in relation to protein is the "optimal" amount for physical performance of various intensity, or the amount which will keep a person in nitrogen balance, it should not be overlooked that the requirement for high quality protein is increased during periods of growth. In most forms of athletic training an increase in muscle mass will occur, requiring additional protein for the building of tissue even if the subject has completed his normal growth period.

Consumption of excess protein during training which involves heavy muscular work has been recommended on the basis of some of the more recent works. Yamaji [*62,63*] based his conclusion on the results of a study in which he noted positive nitrogen balance during the training of the subjects; there was greater nitrogen retention in subjects on a daily diet providing 2 gm. of protein per kg. of body weight than in those on a diet providing 1 to 1.5 gm of protein per kg. of body weight. Yamaji noted decreased blood hemoglobin and albumin during the beginning of the training period. The extent of decrease of these constituents and the rate of return to normal were influenced by the protein intake. This was believed to show that muscle was formed at the expense of blood proteins. In another study Teruoka and Saito [*52*] determined the nitrogen excretion of 20,000 Japanese workers classified by age, sex and occupation. They found a correlation between the urinary nitrogen excretion and the intensity of work. They concluded that for adult workers, 1 gm. per kg. of body weight of protein of good quality is a minimum requirement and that with heavier work, protein intake should be increased.

Under normal circumstances, protein requirements should be met by well balanced meals provided during training. While excess high quality protein in the form of meat or milk will not increase efficiency, it will insure the supply needed for maintenance and growth. It appears desirable from what has been mentioned, not to have too much fat accompany this fairly high level of protein intake. Avoidance of an excessive fat intake may be desirable on the basis of other health considerations, such as prevention of atherosclerosis.

VITAMINS AND PERFORMANCE

As in the case of caloric undernutrition, the impairment of the ability to perform work efficiently in cases of frank vitamin deficiencies is well known [*1,2,5,60*]. It is often more difficult to recognize borderline deficiency states. This may render difficult interpretation of supplementation of particular vitamins on performance, since improvement in such performance may be due not to "supplementation" but to the actual therapeutic effect of the vitamin on an unrecognized borderline deficiency.

When the diet is presumably adequate in vitamins, supplementation might conceivably

affect the efficiency of the energy-releasing reactions chiefly involving the fuel foods, carbohydrates and fats although we know of no evidence to support this view. Thus the members of the B complex group have been studied in relation to effect upon performance with the idea that a more than adequate supply might in some way be helpful in meeting the additional stress imposed by exercise. Through experimentation on twelve healthy subjects whose diets were considered adequate, Simonson and his associates [50] studied the influence of surplus B complex upon their performance in five different types of muscular work. Although there was no beneficial effect observed in these tests, it was noted that eight of the twelve subjects did increase the fusion frequency of flicker which may indicate less fatigue of the central nervous system. In an extensive series of studies by Keys and co-workers [36] upon a group of pretrained army men receiving adequate diets, no beneficial effects of the surplus of five B complex vitamins and ascorbic acid were observed in tests of endurance, resistance to fatigue, recovery from exertion or muscular ability. Studies in this same laboratory [37] on four healthy young men maintained on adequate diets with varying amounts of vitamin B_1 administered at four levels ranging from 0.23 mg. per 1,000 calories to 0.63 mg. per 1,000 calories indicated no beneficial or detrimental effects upon performance in muscular, cardiovascular, psychomotor and metabolic functions over the four series of experiments, each ten to twelve weeks in duration.

Montoye [42,43] has concluded that there is not sufficient evidence to recommend vitamin B_{12} supplementation among athletes. In laboratory tests of strength and pulse rate recovery following work on a bicycle ergometer there was no evidence of beneficial effects of supplementation. In other tests on boys in an institution, he was unable to find positive effects of supplementation on running performance or on performance in the Harvard step test. On the other hand, Bourne [8] concludes from a review of literature that there must certainly be an increased demand for the B complex vitamins during exercise because of their important role in so many of the biochemical reactions which make energy available for muscular work. Vytchikova [58] has also proposed an increase in the thiamine content of rations given athletes above the usual level of 1.5 to 2 mg. per day on the basis of experimental evidence indicating increased B_1 and pyruvic acid in blood following exercise. Supplementation of the diet with 10 to 20 mg. per day of B_1 reduced the level of pyruvic acid in blood to the value found in manual workers and improved reaction time before and after training.

Keys [34] concludes that in cases in which work is substantially increased there is justification for an increase in the intake of B complex vitamins even though there has been no definite proof in man that the requirements for vitamin B_1 is proportional to the intensity of metabolism. Adequate intake of vitamins as well as of other nutrients will be obtained in meals that are well balanced.

GELATIN, GLYCINE, CREATIN AND PERFORMANCE

Among the many proposed ergogenic aids, gelatin with its abundance of glycine has often been considered. It was hypothesized that a diet supplemented with glycine (a precursor to creatine) might increase the concentration of creatine and thereby the potential supply of high-energy phosphocreatine in muscles [34].

Maison [40] tested the effect of glycine and gelatin on endurance of finger extension and demonstrated no beneficial effect of either substance. Horvath and his associates [30] found that glycine supplements did not increase muscle strength or improve the ratio of training in hand dynamometer tests. Gelatin intake (which is approximately one-fourth glycine) did not alter creatinine excretion, nor did it produce changes in creatine excretion that could be attributed to glycine alone. Robinson and Harmon [48] investigated the effects of gelatin upon exhaustive muscular work on the treadmill and in track exercises and reported that gelatin intake did not affect the oxygen debt. On the basis of his review of work on this subject, King concluded "that claims made for especial value of aminoacetic acid or gelatin in the treatment of fatigue or increased endurance are unfounded on theoretical grounds and that protein of the ordinary diet is fully capable of supplying the aminoacetic acid required by man" [38].

ELECTROLYTES, ACID-BASE BALANCE AND PERFORMANCE

It has been suggested that the ingestion of certain alkalinizing agents might alleviate

fatigue or shorten the recovery period following strenuous exercise. This hypothesis was based on the notion that such agents might compensate lactic acid in terms of acid base balance. Johnson and Black [33] could find no significant difference between the effects of glucose, phosphate and a buffer supplement on timed performance during a season of competitive cross-country running. In his evaluation of claims made by Embden that phosphates administered to soldiers on long marches increase the total output of work by more than 20 per cent, Bøje [7] noted the possibility that this effect was due to the subjective feelings of zest associated with such preparations. He also warns of the possible detrimental effect of administered alkali through interference with the pH regulatory system of blood.

The need for supplements of salt in the diet should not be great unless the athlete is training under unusually hot weather conditions. In their work on sodium chloride intake in relation to work performance under hot, dry conditions, Taylor and co-workers [51] concluded that moderate intake of salt is important to the preservation of cardiovascular function and to maintain the ability to work. Excessive intakes of salt resulted in greater loss of salt and water in urine. If supplementation of salt beyond the ordinary seasoning of foods is deemed advisable for the conditions under which the athlete will perform, additional amounts may be taken with the meal or in the form of salt tablets.

ALCOHOL, CAFFEINE AND PERFORMANCE

The use of alcohol in the training program is considered detrimental in that the type of toxicity it produces on the central nervous system affects the finer coordination movements when taken in smaller quanitites, and gross coordination when taken in larger amounts [7].

The use of coffee or tea may provide stimulation to the individual, although studies on performance have given divergent results as to their effectiveness [7]. Individual variation in response to the effect of caffeine on the central nervous system may account for these differences. The use of pure caffeine or other stimulants is not advisable because of the risk of taxing the individual beyond the safe limits of physical capacity. While stimulants or drugs might mitigate awareness of fatigue on the part of the performer, the ultimate risk to his health is of the utmost importance.

SUMMARY AND CONCLUSION

The optimum diet for an athlete in training is not essentially different from that of any normal person. However, certain modifications may seem advisable for the particular circumstances under which the athlete is to perform. To meet the standards of nutritional adequacy, the diet should comply with the needs of the individual in terms of growth, maintenance and superimposed activity requirements. Prior to the training season it is desirable to assess the nutritional status of an athlete to determine specific needs for weight gain or loss so that the dietary may be planned accordingly.

While undernutrition and malnutrition (including obesity) impair performance, supplementation of presumably adequate diets has not generally given clearly defined results. The multitude of problems encountered in the experimental studies designed to test the usefulness of such supplements do not always rule out the effect of motivation and progressive training. Furthermore, the conditions under which these tests had to be made may not be applicable to the performance in the athletic field. In general, it appears that eating no less than three meals a day represents a desirable pattern for athletes. When the sports practiced are particularly protracted and exhausting, up to five lighter meals may be preferable. Available evidence indicates that the relative composition or size of the meal preceding an athletic event of short intense duration is generally unimportant to the performance of the athlete. However, in sports which demand endurance and prolonged activity, there is evidence that performance is better maintained if the person is on a high carbohydrate diet rather than on a high fat diet if these diets have been consumed for several days prior to the event. In such cases even a slightly increased efficiency (the minimum figure of 5 per cent has been indicated by many investigators) in subjects on a high carbohydrate diet may well make a difference in the outcome of a contest.

Wide variations of protein intake do not seem to influence performance capacity. In a well balanced diet the protein requirement for maintenance and growth should be easily met.

While vitamin supplementation to adequate diets appears to give no additional beneficial

esults, the paucity of evidence does not rule ut the possibility of increased demands imosed by hard muscular work.

The use of other proposed ergogenic aids such s gelatin and phosphates has yielded either o beneficial results for performance, or in some ases equivocal results possibly due to subective influence.

Because of deleterious effect on coordination, lcohol should be avoided during training. Coffee, tea, or other beverages containing caffeine may produce some stimulation to the individual by decreasing awareness of fatigue but their use in large amounts is not recommended.

The use of salt above the amount generally contained in a meal appears to be necessary only under unusually hot climatic conditions.

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Evaluation and Treatment of Muscle Function in Athletic Injury

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ATHLETIC injuries are those produced by circumstances inherent in respective athletic performance. They are, therefore, characterized by exposure to recurrent identical trauma and strain, making reinjury likely.

Further characteristics are the exposure of the patient to the strains of top performance requiring restoration of function beyond otherwise "normal" levels, and the frequent need for speed of recovery to the point at which return to the stressing activity can be permitted safely. In other words, the goal of treatment is the restoration of function to the greatest possible degree in the shortest possible time [*10*].

The lessons learned in the treatment of athletic injury exceed the particular application. They can be used to great advantage in the management of occupational injury.

When talking about athletic injury, one is inclined to think primarily of the actual competitive athlete. However, one has to keep in mind that most of the injuries will occur not to the top performers but to the occasional week-end athlete. The once a year skier, or once a month tennis player, is in greater jeopardy than the person who keeps in reasonably good shape physically and in constant practice at his athletic activity.

Rehabilitation of the athlete with an injury deals primarily with restoration of muscle function, and prescription of treatment should therefore be based not only upon the status of bone and joints proper but equally upon consideration of the status of muscle.

Normal muscle function is restored by a training program. The same rules that apply to normal training prevail.

GENERAL CONSIDERATIONS

Such special training should include a well defined prescription of the type of exercise required (quality) as well as the amount of exercise given (quantity and dosage). It will be based on an evaluation of these basic properties of muscle function: strength, the ability of a muscle to contract and overcome resistance; mechanical elasticity, the ability to yield to passive stretch; and physiological elasticity, the ability to relax, to give up tension.

Some general rules apply and should be remembered:

Muscle function will increase only if repeated frequently enough and intensely enough in any single exercise period. The gain made in this period will only be permanent if successive exercise sessions follow closely enough and are conscientiously carried out for a long enough total period.

The movements performed must be identical in order to repeat identical function of identical muscles (to avoid substitution). The function desired must be performed with enough intensity (dosage) to exceed easy performance. Repeated performance of a function in large enough dosage will cause the development of the desired quality.

The value of an exercise, its ability to develop a given quality, we call "exercise value." (Fig. 1.)

STRENGTH OF MUSCLE

Before prescribing strengthening exercises, strength of muscle should be graded. One of the frequently used methods of grading differentiates between six degrees of strength.† Evalua-

† No voluntary contraction noticeable; traces of voluntary contraction noticeable; poor muscle power, muscle can produce movement if assisted and if gravity is eliminated; fair movement can be actively produced without assistance and against gravity; good, as fair movement, plus ability to overcome resistance, but less than normal; and normal.

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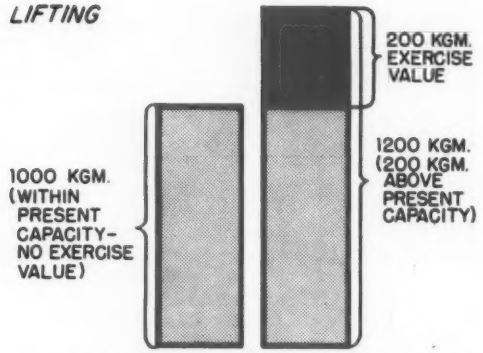

FIG. 1. To obtain exercise value, exercise should exceed easy performance. (From: KRAUS, H. [5]. Principles and Practice of Therapeutic Exercises. Springfield, Ill, 1956. Charles C Thomas.)

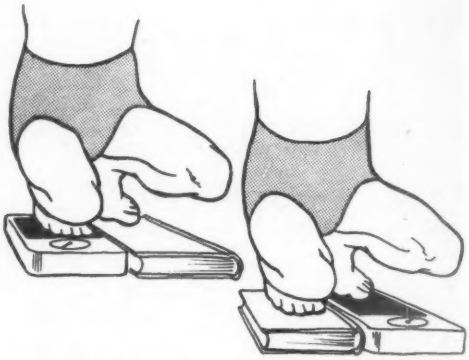

FIG. 2. Scale test to gauge strength of injured extremity.

tion of strength in the lower extremity of the athlete or heavy worker should include a comparison with the contralateral side by weight lifting or the scale test. (Fig. 2.) The patient stands on a bathroom scale with the injured foot and on an equally high book or piece of wood with the other. He is asked to squat and then raise himself to a standing position. The weight taken on the injured side is noted. Then the procedure is reversed to compare how much weight the other extremity will take. The difference gauges the total weakness of the injured extremity.

In sports in which the lower extremity is especially jeopardized, such as skiing, football, soccer and ice skating, a return to normal activity should not be permitted until the injured side is at least as strong as the uninjured one.

Strength of a muscle will be increased if the demand of exercise exceeds easy performance. Severity of performance depends upon resistance or the load to be carried by the muscle, and by the number of repetitions. Generally speaking, many repetitions and exercises with low weight will increase endurance rather than strength; high resistance will increase strength. Normally, a muscle should be exercised to tolerance but not to fatigue. Only a very strong, almost normally strong, muscle lends itself to "fatigue work [5]."

Strength-building exercises with too little exercise value do not increase strength or do so only very slowly. It is essential to give a sufficient quantity of work. On the other hand, these exercises given in too large dosages may result in pain and decrease of strength, at least temporarily. (Fig. 3.)

Strength-building exercises should, in the majority of cases, be given below fatigue level. In very weak muscles fatigue may decrease the ability to exercise so far that the muscle cannot perform at all. Several days of rest may be necessary before resuming exercises. By then the initial gains may have disappeared and training will have to be started all over again, only to produce the same negative results if pushed past the fatigue limit [12]. Fatigue may increase contractures, produce pain and painful muscle spasm.

Depending on the strength or weakness of the muscles, resistance may vary from "assistance work" with gravity eliminated, to work against gravity, or work with weights or resistance. In a stronger muscle, weight with resistance is a satisfactory means especially if carried out systematically. The Watson-DeLorme system of weight lifting is one which has proved very effective [2].

Often active resistance, given by a good therapist, offers considerable advantages. This is true for a number of reasons. The effectiveness of the muscle varies at the various sectors of joint range, and in order to complete range, "weight work" will have to be limited to the maximum weight that can be lifted through full range. (Fig. 4.) This will generally be much less than the weight acceptable in the sector of maximum capacity. Frequently, strengthening as well as stretching of tight muscles must be performed in the injured extremity. By manual resistance and assistance this can be done in one act whereas this is impossible when working

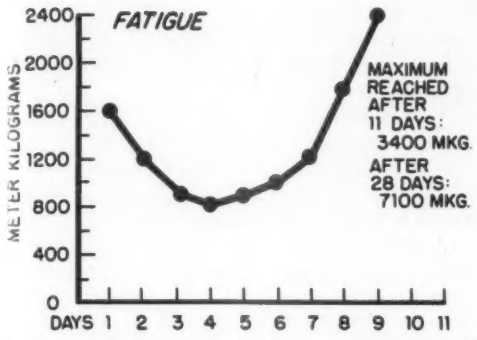

FIG. 3. "Fatigue graph" indicating performance on successive days under fatigue work [12]. (From: KRAUS, H. [5].)

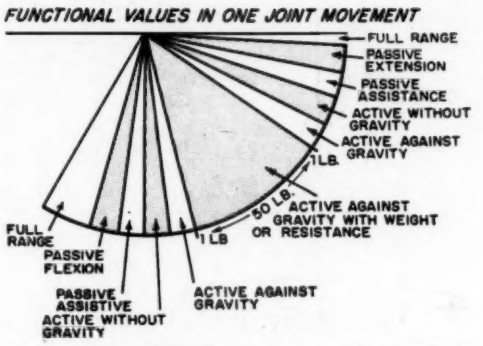

FIG. 4. Manual resistance exercises can adjust to the varying strength and flexibility throughout the joint range. (From KRAUS, H. [5].)

with weights. Intensity of strength-building exercises is specified by weight to be lifted, resistance to be given, and time or repetition of the movements performed [5].

Contracture is treated by first limbering and then stretching of muscle. Limbering is an easy movement performed well within easy range. The muscle is first warmed by limbering movements, then by resistance to tightened muscle as well as to the antagonist, then active stretching, that is the attempt of the patient to go through the full range of motion and beyond, and finally passive stretching should be instituted.

One should never stretch before the muscle has given up all contraction (is completely relaxed) and one should not try to stretch a tight muscle. A muscle in painful spasm should never be stretched.

As in strength-building exercises, stretching must exceed easy performance to produce exercise value. (Fig. 5.)

The reluctance of many to permit passive stretching is based primarily on stretching performed with improper indication or excessive violence. Proper passive stretching is an essential part of therapeutic exercises, and its adverse effects can be completely avoided if proper indication and proper technic are observed. It should be prescribed when necessary. Reluctance to use it because misuse leads to adverse effects is just as unjustified as it would be to stop surgery because some surgical results are not satisfactory [5,7].

Physiological elasticity, the ability of a muscle to give up tension, is highly important for normal movement.

A tired muscle loses some of its ability to relax. The endurance of a muscle is, therefore, characterized not only by its ability to produce power over a prolonged period of time but also by its ability to maintain elasticity at the same time. An endurant muscle readily assumes its maximum length after repeated or long contractions. A fatigued muscle loses part of its ability to return to its maximum length.

The ability of a muscle to give up tension, to relax, can be affected by various causes. Herein we are only interested in two: the difficulty in relaxing as present in "tension syndrome," and the inability of a muscle to give up tension in muscle spasm.

Muscle spasm is present if the muscle is forced to maintain a state of tension and contraction by pain to the lower motor neuron. The characteristics of a painful muscle spasm are pain and inability to give up muscle tension.

In tension, the ability to release and relax, is reduced. The muscle is in a state of tension in excess of the need of performance. This "tension state" of muscles is very frequent in our overstimulated and underexercised population.

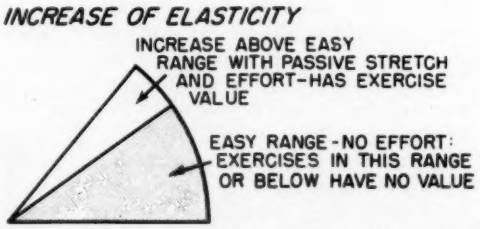
INCREASE OF ELASTICITY
INCREASE ABOVE EASY RANGE WITH PASSIVE STRETCH AND EFFORT-HAS EXERCISE VALUE
EASY RANGE-NO EFFORT: EXERCISES IN THIS RANGE OR BELOW HAVE NO VALUE

FIG. 5. Stretching exercises have exercise value only if exceeding easy present range.

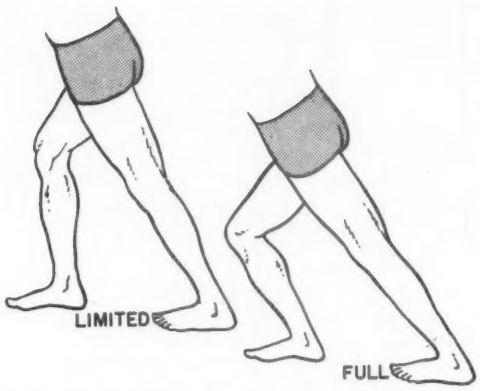

FIG. 6. Testing of flexibility, length of soleus muscle of right foot.

People consistently suppress irritation which should find release in motor response. The constant suppression of the fight and flight reaction is responsible for many of the tension states, and these states are frequently coresponsible for athletic injury. It is important to be aware of these reactions and hypertensions when treating athletic injury.

Relaxation training is given to relieve muscle tension. Relaxation is actively taught by demonstrating to a patient tightening and relaxing of a muscle over which he has good control, such as biceps, then a carry-over to areas that are habitually tense.

When mechanical elasticity is impaired, the muscle does not yield to passive stretch. This state of muscle shortening (Contracture Tiegel) is frequent after injury as a consequence of painful muscle spasm or prolonged immobilization, or both. In athletic injury contracture is usually confined to this state of muscle shortening and is not complicated by actual fibrous contracture.

Limitation of motion caused by contracture is measured by a goniometer. Here, too, the range of the lower extremity should be gauged with and without weight bearing. Ankle flexion, for instance, may be full without weight bearing in both positions, knees straight and knees flexed, but it might be decidedly limited with weight bearing as in the "Vorlage" position. (Fig. 6.) This limitation of motion is particularly important whenever full range of ankle and flexibility of calf muscle are needed, such as in tennis, jumping, skiing, etc., and frequently indicates lack of muscle resilience. A knee joint may have full range in a lying position but there may be a difference in kneeling which constitutes a residual tightness of importance.

Painful muscle spasm is a clinical picture in which increased contraction of a muscle is associated with pain. The muscle is unable to give up a state of permanent contraction, and the result is painful limitation of motion.

Painful muscle spasm is almost always present in acute injury. Should severe trauma be present, treatment of painful muscle spasm will have only palliative value, if any at all. Severe spasm may be started even by minor injury (such as sprains and strains). In these cases, symptomatic treatment of pain and muscle spasm may restore normal motion and minimize or prevent the consequences of trauma.

In long lasting painful muscle spasm, the muscle is contracted and frequently held in that state for a long time. Permanent loss of muscle elasticity and shortening, contracture, of affected muscle are frequent.

Muscle spasm is treated by relief of pain or raising of the pain threshold plus gentle active motion. Relief of pain can be attained in various ways. Among local means helpful in relieving muscle spasm are use of tetanic and sinusoidal currents, application of hot packs and the use of locally administered surface anesthetics such as Novocain® iontophoresis and ethyl chloride spray. The latter is an easy and constant method [*5,6,8,13,14*].

The pain is located by active motion. Ethyl chloride is then sprayed on this area. The patient then starts active movement of the part involved, in the direction in which motion has been painful and limited. As the patient increases his range, new painful areas will develop. These areas must again be sprayed and active motion continued. Treatments last from ten to thirty minutes and should be carried out within limits of pain.

Immediate use of the affected part may be allowed in patients able to perform normal movement, but excessive strain and sudden movements should be prohibited. Patients with more severe disabilities should be advised to rest, but all patients should be urged to continue the active movements they have been taught. The exercises should be performed from a minimum of twice a day to as often as once every hour, for approximately five min-

FIG. 7. Use of ethyl chloride spray for sprained ankle.

utes. While a single treatment will suffice in cases of minor involvement, patients with more serious difficulty require frequent treatment—daily during the first week and later every other day. (Figs. 7 and 8.)

An effective treatment should not require the application of an anesthetic after the second week. Therapeutic exercises must be continued and increased in scope until normal muscle power is restored. Once motion is instituted, immobilization should not be used as it is contrary to the basic principle.

It should be stressed that active motion, although unquestionably necessary, should never be brusque or abrupt so that muscles in painful spasm will not be further aggravated.

Compared with injection of procaine hydrochloride into the muscles and ligaments, the use of ethyl chloride has certain definite advantages: (1) The application is simple. (2) Repeated application is possible with minimum difficulty and risk. (3) Large areas can be controlled that would otherwise require quantities of procaine hydrochloride. (4) Ethyl chloride does not mask injury to bone or ligament. (5) It is preferable as a diagnostic means since it is more selective. (6) There is less risk of a local aftereffect and there is no general aftereffect such as occasionally occurs after the administration of procaine hydrochloride. (7) There is no danger of infection.

The administration of surface anesthesia is only the first step in the treatment of painful muscle spasm. Exercise is the necessary second step. Without it, the use of surface anesthesia would accomplish little more than the use of gas or ether in surgery without operation.

Exercises must be performed immediately after application of the anesthesia. These should be exercises to restore elasticity and increase relaxation and length of muscle, and should always be performed below the limits of pain and fatigue. Scattered dosage from two to five minutes, and exercises every one-half to one hour should follow. The supporting pre-

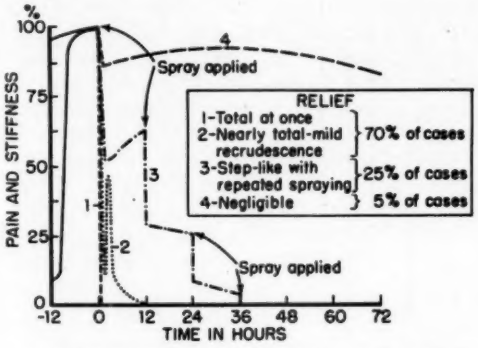

FIG. 8. Effectiveness of ethyl chloride spray in treatment of muscle stiffness (stiff neck) [13,14].

scription may call for particular or complete rest between exercises.

The most common mistakes made in treatment with surface anesthetics and exercises are as follows: (1) Failure to cover the full painful area with anesthetic; (2) overdosage of violent exercise; (3) neglect of pain limit; (4) neglect of home exercises; (5) neglect of supportive prescriptions; (6) neglect of follow-up treatments; (7) failure to explain properly to the patient and to arouse the necessary cooperation; and (8) faulty indication.

As to the theory involved, pain originating in one portion of the sensory motor chain leads to reflex muscular spasm and locking of joints. (Fig. 9.) This sensory motor chain consists of the following elements: sensory nerve, nerve center, motor nerve, muscle and sensory nerve. Pain originating in the course of this chain

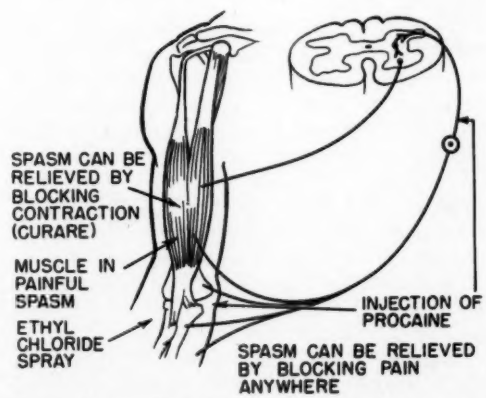
SPASM CAN BE RELIEVED BY BLOCKING CONTRACTION (CURARE)
MUSCLE IN PAINFUL SPASM
ETHYL CHLORIDE SPRAY
INJECTION OF PROCAINE
SPASM CAN BE RELIEVED BY BLOCKING PAIN ANYWHERE

FIG. 9. Interrupting the sensory motor chain at any point may help to relieve muscle spasm.

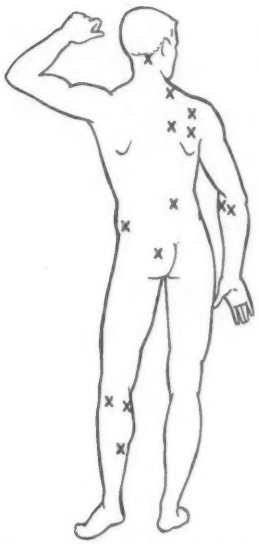

FIG. 10. Some common locations of triggerpoints.

leads to muscular spasm. Elimination of pain at any point in the chain results in the breaking of the chain, and, therefore, in relaxation of the muscular spasm. This may be achieved directly by the injection of an anesthetic into the muscle, joint ligament, sensory nerve or spinal cord.

If the pain-free interval is used to restore the muscle to normal function, spasm does not recur or it recurs with much less intensity. It has been our experience that on the basis of this chain, cutaneously administered anesthesia similarly relieves deep-seated pain in muscular spasm.

There is no adequate scientific explanation for the deep effect of surface anesthesia. However, the underlying physiological reason presents an interesting field for exploration; and, it should again be emphasized that surface anesthesia alone, without active motion, will not achieve good results.

Besides muscle spasm, other painful conditions of the soft parts must be considered:

Fibrositis is a condition of exquisite tenderness of the skin. There is little or no limitation of motion. Therapy consists of pinching massage.

Myositis exists when muscle is tender to touch. Usually the muscle is tight as well, and tightness may result in limitation of range. Treatment is generally kneading massage with use of sinusoidal current followed by ethyl chloride spray.

Different from myositis is localized, well defined tenderness in muscles, "triggerpoints" [*4,5,14*]. These can sometimes be palpated as little nodules and frequently occur in muscles as a late effect after injury or sometimes as the result of chronic or acute muscle strain. (Fig. 10.) Treatment of triggerpoints consists of injection of Novocain or saline (equally effective) into the tender spot.

The spot is palpated and marked. Then with a sterile technic a needle is inserted until the spot can be felt as a harder and more resistant object in the path of the needle. The patient can usually corroborate by indicating the pain at this moment. Ten, twenty or more cubic centimeters of saline are then injected while the needle is retracted and reinserted, fanning out through the whole triggerpoint. Three follow-up treatments with sinusoidal current and ethyl chloride spray to relieve subsequent spasm are important to avoid the need for frequent reinjection.

Return to athletic activity should only be permitted when the injured part has been fully rehabilitated; otherwise reinjury is likely. This is especially important in rehabilitation of the lower extremities.

Gait training and ambulation should not be started before the patient is strong enough to walk properly. This should be hastened by gradually increasing resistive exercises without weight bearing. To expect a very weak or stiff ankle or knee to be limbered up and strengthened quickly by premature or excessive walking is erroneous. Walking only contributes to rehabilitation if the patient walks in a normal fashion. If it is a limp with joint stiffened, and with non-affected muscles substituted for the weak ones, then walking will only prolong disability.

PREVENTION

Much has been written about the role of equipment and rules in the prevention of athletic injury. Of equal or even greater importance is a factor much less often mentioned, namely the physical condition of the athlete himself. It has been shown that lack of physical fitness, and especially of muscular fitness, is one of the most important factors causing accidents in team sports as well as in individual athletic performance. Adequate strength and flexibility

not only relieve the impact of false or rough contact in collisions between players, but make possible a quick reaction to avoid hazardous situations. In "week-end athletes" lack of physical training is frequently responsible for untrained muscles and sprains which are directly due to overtaxing of muscles and joints.

Just as good conditioning in general is an important factor in preventing athletic injury, the condition at the actual time of performance carries heavy weight. A "warmed-up" muscle is more flexible and gives more easily in a fall and in violent sudden movements [3]. Thus a good warm-up is essential to avoid strains, sprains and even fractures.

In fatigue, stiffening of the muscle as well as slowed-up reaction time contribute to the hazards.

It should, therefore, be the effort of every physician who supervises athletes not only to take care of their injuries but also to make sure that they do not participate unless they are in good physical shape, and that they do not perform and especially do not compete without proper warm-up or when fatigued. The fact of physical preparedness before performance is, of course, especially true after injury and has been discussed at length before. A patient may be perfectly fit for his civilian occupation yet be a very poor risk and unsuited for tentative performance of his athletic activity. Again, the occasional athlete or the week-end athlete is the one who is most exposed to danger. He is usually in rather poor physical condition, with little margin to spare in meeting possible hazards; when he resumes activities after injury, this poor physical condition has generally worsened and is aggravated by local deficiency after injury [10].

In competition, especially in team sports or in contact sports, matching reasonably equal opponents and fitting them to a reasonably equal team is essential.

In our sedentary civilization, athletic activity is essential and should be part of every child's education beginning at a very early age. Athletic activity, however, does not mean competing, and competition should not be started before the child is well and ready for it. Athletics in the wider sense, especially running and outdoor activities should be part of education at the very earliest age. One must not forget that the chance to run about, to crawl, to climb trees and to play with animals, the very activities which used to make children healthy and strong, are removed from the average city child and therefore have to be substituted for by conscientiously directed programs. Overprotection will only result in eventual defeat. It is better for a child sometimes to suffer injury than never to be given a chance to be exposed to such injury. Protection up to ten or twelve years followed by sudden exposure to competition is a definite hazard. Children who have led active lives, however, should eventually be permitted to compete.

INDICATIONS AND EXAMPLES OF TREATMENT

All fractures, sprains and strains should be considered potentially in need of therapeutic exercises, either to prevent loss of strength and flexibility, or to restore them when loss could not be avoided. These programs may in some cases consist of proper advice on how to use the injured extremity, in others of prescribing definite movements, and in others of well defined and regularly carried out exercises.

In the management of trauma, the decision is generally whether to mobilize or immobilize. The ultimate goal of achieving the best function in the shortest time can be best attained if the muscle which is the motor is remembered at every turn of the way. Immediate mobilization frequently leads to good results, and a few instances should be enumerated [9]: (1) Fractures of thoracic and lumbar vertebrae without neurological complications, if these fractures do not comprise the pedicles; (2) fractures of the rami pubis of the pelvis if uncomplicated; (3) fractures of the acetabulum may need traction before mobilization, but frequently they respond best to immediate mobilization through exercise, which is performed with the patient lying down, postponing weight bearing for many months; (4) many fractures of the plateau of the tibia do very well when immediately mobilized, with or without balance suspension; and (5) fractures of the fibula and fractures of the short bones of the foot (especially the os calcis, if uncomplicated), as well as those of the metatarsals, frequently progress better without fixation but with immediate mobilization provided the existing position can be accepted.

In certain fractures of the upper extremity, such as impacted fractures of the head of the humerus and fractures of phalanges and meta-

carpals, disability can be shortened by many weeks if they are mobilized instead of splinted.

When internal or external fixation is indicated, therapeutic exercise to maintain function should be instituted from the start. Exercises should be given locally, and, especially in the case of bed rest, should include breathing exercises and trunk strengthening exercises. Whenever the lower extremity is affected, strengthening of the upper limbs, especially of the triceps, will help prepare the patient for walking with crutches.

In sprains of joints and in muscle strain, the decision to mobilize should be based on whether or not there are major tears. Treatment should first deal with relief of muscle spasm using locally-administered surface anesthetics and gentle limbering motion, and then proceed to strengthening and limbering of the affected muscles. Swelling of the joints, if not excessive, is an indication rather than contraindication for immediate mobilization. When dealing with the lower extremity, this mobilization should be performed in bed, without weight bearing. It gradually requires an increased program, postponing walking with crutches and actual weight bearing until the extremity is strong enough for the task. If the patient cannot ambulate without limping and stiffening parts of the lower extremity, he should not be forced to walk since this will retard rather than accelerate the speed of recovery.

The same principle applies to acute strains of the back. Once the acute spasm has been relieved, it is necessary to test the strength and flexibility of key posture muscles. In order to avoid recurrence, weak muscles should then be strengthened and tight muscles (usually back and hamstrings) should be limbered and stretched. Before the patient returns to work, it should be ascertained just what degree of physical activity will be demanded. Managing body weight successfully will be sufficient for the sedentary occupation, but the same degree of fitness will not be adequate if the patient has to lift or otherwise perform heavy labor. Since physical work very frequently requires spurts of effort, one cannot expect the patient to be rehabilitated on the job. He must prepare his strength and flexibility to meet those peaks of effort. The final examination to determine ability to return to work should, therefore, always include muscle evaluation. Weakness, spasm or contracture may be contraindications as important in the long run as unsatisfactory roentgenograms. If the patient is not found adequate to the demands of his occupation, gradual return, limited working hours, and limited work should be prescribed. Overtaxing his muscular potential could otherwise prolong disability and jeopardize full recovery.

Sprained Ankle. A ligament tear causing instability should be either repaired or immobilized. The following treatment applies only to sprains without such complications. Bring the ankle into a relaxed position with the patient supine with pillows under the knee and foot. Spray the painful area with ethyl chloride, ask the patient to move in flexion-extension, and generally assist, resist and aid the movement. As the pain shifts, continue spraying. Once maximum relief has been reached, add inversion, eversion and toe flexion-extension, always following-up the pain with the spray. In mild and moderately severe cases have the patient attempt walking, follow-up the pain with spraying; then, if possible, have the patient stand on his toes and bend forward with his heels on the ground. If more severe, have the patient perform movements only without weight bearing. In these cases advise the use of crutches, repeat the treatment daily and ask the patient to exercise by himself for one to two minutes every half-hour and stay off his feet. Institute resistance and stretching exercises as well as weight bearing exercises, toe standing, soleus muscle stretching, and eversion standing as soon as possible. As in all minor athletic injuries, the aim of treatment is the shortening of the period of disability and the restoration of full function. For a person in a sedentary profession without any athletic aspirations the same sprain might not require any treatment at all or could be cared for with an Ace bandage.

Partial Tear of the Medial Collateral Ligament of the Knee Joint. The patient should be placed in a relaxed position with a pillow under the knee. Use spray for tender and painful areas, institute movements: flexion extension with emphasis on extension, and quadriceps setting. Add extension with a pillow under the knee and extension over the edge of a table with resistance, if tolerated. In minor cases add standing exercises, include knee bends and kneeling. In more severe cases rest will be essential and exercise as previously indicated on the half-hour. No weight bearing should be per-

mitted before the quadriceps are strong enough to permit normal walking.

Acute Back Strain. Acute muscle spasm, such as may be present during severe attacks, is treated with surface anesthesia, primarily ethyl chloride spray or procaine iontophoresis. In this procedure, the patient is placed on his side with his knees slightly flexed. Ethyl chloride is sprayed on the painful area, and at the same time the patient is asked to pull his knee up to his chest, then gently to return it to its former position. This movement is repeated three or four times on one side and then on the other. The patient is constantly urged to indicate the painful area with his finger, and the spraying follows the shifting pattern of pain. This treatment is continued for fifteen to twenty minutes, until pain is relieved as much as possible. The patient is advised to avoid remaining in one position for too long. He is instructed to perform the simple exercise just described possibly every half-hour, or, in less severe cases, every hour, for two to three minutes. Patients with more severe cases were advised to stay at home, but bed rest is avoided if possible and steady alteration of position is advocated.

The same procedure is used for immediate mobilization of fractures of the transverse process of lumbar vertebrae, for spinal fractures lending themselves to immediate mobilization, or for fractures of the os pubis.

Fractures of the Lower Extremities. Spiral fracture of the tibia and fibula may serve as an example. Let us assume this fracture was treated either by internal fixation or immobilization in plaster reaching up to the hip joint. In this plaster only some quadriceps setting will be possible, not more. This and flexion and extension of the toes against resistance should be performed frequently by the patient for the first day. As soon as the knee is free for movement, flexion-extension of the knee joint with emphasis on extension, and quadriceps setting as well as extension of the knee over the edge of a table and on a pillow should be instituted. Extension of the knee against gravity should not be permitted until it can be carried out to 180 degrees in order to avoid "freezing" of the knee with extension limited. When the plaster is completely removed, exercises *without* weight bearing should include resistive exercises to ankle movement and toe movement as well as very gentle stretching exercises to stretch tight muscles where tightness exists. Weight bearing should not be permitted without crutches until the patient can walk without limping. This prevents unnecessary tightening of hamstring and calf muscles as well as unnecessary pain, and usually speeds up ultimate recovery.

An important principle in rehabilitation of the lower extremity is not to permit weight bearing before the extremity is functionally ready. The usual advice should be to walk only as much as one can without limping, and partial weight bearing should be handled in an analogous way.

The Tennis Elbow. This may serve as an example of treatment of sequela of injury or chronic athletic injury. The usual examination should be supplemented by palpating the muscles of the forearm and arm above the elbow. Frequently, triggerpoints can be located; the most frequent site of these is in the ulna and radial group of the forearm muscles, sometimes in other muscles around the elbow joint. Injection of saline solution into the triggerpoints, followed during the next few days by gentle massage or the use of sinusoidal current for the tender muscle groups, frequently helps, especially in cases in which the tender spot is situated well in the muscle and not right at the bony prominence of the condyle. Triggerpoints at the epicondyle proper respond better to local injection of Hydrocortone.® If they are not accompanied by muscle tenderness and soreness, aftertreatments are usually unnecessary.

As in all chronic strains, the cause must be carefully eliminated to avoid recurrence. It may be flipping of the wrist in top spin or in faulty backhand, or it may be a new racquet with a handle that does not fit the player's hand, or it may be changing from one "style" to another that produces difficulties. Tennis elbows are frequent occupational hazards of musicians or occur in other occupations requiring identical repeated movements. The actual cause, faulty movement, must be well established and eliminated to avoid recurrence as soon as the activity is resumed.

SUMMARY

Since athletic injuries are caused by circumstances characteristic of the sport, the patients are subject to recurrent identical trauma. This as well as the need for early return to the

athletic activity makes early and complete rehabilitation essential.

Weakness and stiffness after injury are among the main causes for reinjury. Therapeutic exercises to restore full function of the injured part are essential for a safe and speedy return to the sport.

Treatment of athletic injury, therefore, stresses early—often immediate—mobilization after fracture, sprain and strain. The technic of exercise and local treatment to relieve painful muscle spasm are described.

Good physical conditioning and adequate warm-up are the most important measures in the prevention of athletic injury.

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Protective Football Equipment

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WITHIN the past decade, associated with an increasing public interest in sports and physical fitness, an awareness of the importance of protective equipment in various sports has arisen. Improved safety mats in boxing and wrestling, newly designed helmets in baseball and polo, release bindings in skiing, and newer and better shock-absorbing materials in many contact sports have been introduced and found to afford more protection to the athlete than existed heretofore. In football, too, supported by well controlled laboratory studies, newer equipment improved in design and basic construction has gradually come into use. A presentation of current trends in the use of protective equipment in football is of timely interest, and it is our aim to describe the new apparatus and discuss their relative merits.

THE FOOTBALL HELMET

A glance at the catalogs of the athletic equipment sales houses and manufacturers reveals the existence of a remarkable variety of football helmets, and shoulder and hip pads. A survey of the football coaches throughout the country shows a diversity of opinion as to the protective efficacy of one piece of equipment over another. One wonders why such a wide range of opinion exists until he realizes that so many variables enter into the evaluation of football equipment on the field that accurate judgment is rendered extremely difficult and, at best, only general impressions can be obtained by the unbiased observer.

For example, it hardly need be denied that a powerful blow of the knee delivered at exactly the right angle to the head of a would-be tackler will render the latter unconscious regardless of the type of helmet he is wearing. As a corollary to this, a football squad with heavy, hard-running backs is likely to show a higher incidence of injuries to the head sustained in practice.

Then, too, it is well known that some athletes are more concussion-prone, usually a residuum of injuries to the head received in pre-college years. The reported incidence of cerebral concussion will rise in a squad with an inordinate proportion of players of this type, unless they are interdicted from further participation. Finally, it is well recognized that an athlete may have the stigmas of concussion, including headache and loss of orientation and memory for recent events, without having lost consciousness. Sometimes, for one reason or another, this condition of the player may escape the attention of the trainer and team physician. Obviously the recorded incidence of cerebral concussion in this squad will be lower than what actually exists. For these several reasons, then, it is apparent that it is difficult not only to gather accurate statistical data on concussions but also to evaluate the protective value of a football helmet on the field. Until such a time as carefully controlled large-scale studies are made with a proper weighing of the variables involved (a project of no small undertaking), reliance must be placed on laboratory studies for the evaluation of protective equipment. The work of Edward Dye, formerly of the Cornell Aeronautical Laboratories at Buffalo, New York, on the football helmet is a prime example of the type of investigation which for the first time subjected a field piece to careful scientific analysis.‡ His article in this issue (see page 368) is necessary reading for

‡ Dr. Charles F. Lombard, formerly at the University of Southern California, and Dr. Henry J. Montoye of Michigan State University are others who have conducted similar analytical studies of helmets in the laboratory.

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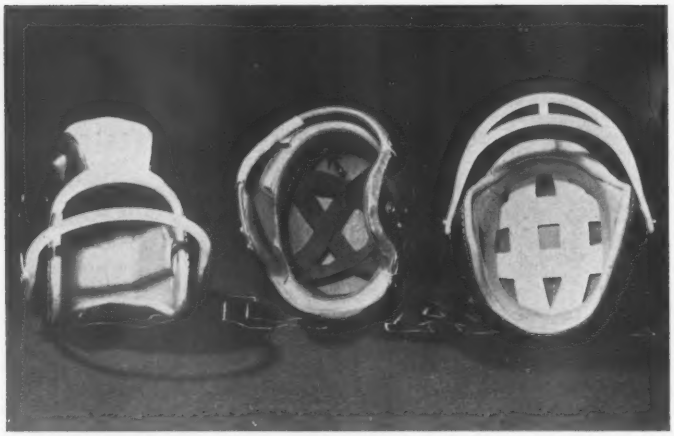

FIG. 1. Football helmets used at Cornell University. Left, fiber-leather shell with single nylon face guard. Arrow indicates panel of Ensolite applied externally to soften blow to opponent. Center, well-worn Cornell helmet with plastic shell, geodetic suspension and (arrow) stiff beam pad in hatband area. Right, plastic shell, double nylon face guard and geodetic suspension.

the student interested in protective equipment.

The helmet designed by Dye was field-tested in 1951 by selected concussion-prone players of the Cornell University football team. The results tended to bear out the high rating of the helmet obtained in the laboratory. However, high-cost production problems on the manufacturer's level have delayed mass production of the model helmet, which combines the essential features of a rigid shell, geodetic suspension and a "beam" pad which extends around the interior of the helmet in the hatband area. (Fig. 1.) On the other hand, both fiber-leather and more recently plastic-shell helmets embodying geodetic suspension, but without the beam pad, have been used exclusively on the Cornell squad for the past few years. A small number of concussions have been reported each year but the consensus among the staff is that the incidence of injuries to the head has declined significantly since the introduction of the new helmet.

Communications from Xavier University in Ohio and from Harvard and Duke Universities, where the plastic shell-geodetic suspension helmet received field tests this past year, gave favorable reports, no instance of concussion being noted among the players wearing it. A further decline in the number of cerebral injuries can be anticipated when the manufacturing difficulties are resolved and the beam pad is incorporated in future models, inasmuch as this structure serves to absorb energy and to stiffen the helmet at the equator, the region where damaging blows predominate.

It should be noted that the experience of the Cornell University football team is limited to the use of helmets which contain geodetic suspension as a common feature. An unsuccessful effort was made to obtain information from leading manufacturers of helmets with a view toward presenting the mechanical features and construction of each along with the Cornell helmet. In the absence of this information, all that can be said for the present is that the Cornell helmet, with geodetic suspension and beam pad, displayed greater shock-absorbing potential than all other helmets in use when tested by Dye in the laboratory.

The search for an ideal football helmet continues. A shell more rigid than the present types, which occasionally crack and deform under blows, is needed. The new epoxyplastics offer some hope in this direction. Some thought has been given to increasing the number of straps in the geodetic suspension, inasmuch as it is demonstrable mechanically that this would increase the efficiency of the suspension. Attention has also been directed to softening the somewhat firm beam pad, which at times has exerted an uncomfortable pressure on the head of the wearer.

FACE AND MOUTH GUARDS

The hard plastic face bar has become an almost universal appendage to the football helmet in recent years, and the rare player who does not wear one stands out among his team mates. The experience at Cornell University with face guards has not been favorable, and it is the general feeling of the staff that they offer more disadvantages than advantages. The number of facial injuries including those of the nose and teeth have not declined. The outriggered appendage frequently serves as a lever and the helmet is driven off the head, thus exposing the player to more severe injury. When these factors are combined with the observations that the face guard tends to inflict injuries to the hands of opposing players and at times obstructs the vision, it can be seen why a second look is necessary to determine whether the face guard offers the protection expected of it. On the other hand, there is no question that the mouth guard provides excellent protection for the lips and the teeth. Where dentists in a community have collaborated in fashioning mouth guards to fit each individual player, injuries to teeth have virtually disappeared. At Cornell University the widely used and deservedly popular Featherbite,®* which is easily and quickly fitted, has prevented injuries to the teeth in all the players who have worn this protective device.

THE SHOULDER PAD

Shoulder pads in current use are classified according to design in three groups: (1) the flat pad which rests on the shoulder, less bulky than the other two types and allowing for more freedom of the arms; (2) the inside cantilever, which is characterized by a bridge extending over each shoulder from front to back and attached to the underside of the body of the pad; and (3) the outside cantilever with the bridge situated external to the body of the pad. (Fig. 2.) Heavy fiber is used as the basic material in the construction of most shoulder pads, but in recent years the lighter "slow recovery," shock-absorbing, closed-cell foam plastics* have been introduced, and shoulder pads of this material or combined in a "sandwich" construction with a layer of fiber in the middle are gaining in popularity. This foam plastic has tended to lighten the pad considerably, offers excellent protection and has become especially adaptable to backfield men. Heavy pads for line backers, modified shapes around the neck, a "snubber" device, which is designed to attenuate a blow to the front of the shoulder, and modifications in strapping are additional features of the various shoulder pads designed to prevent injury.

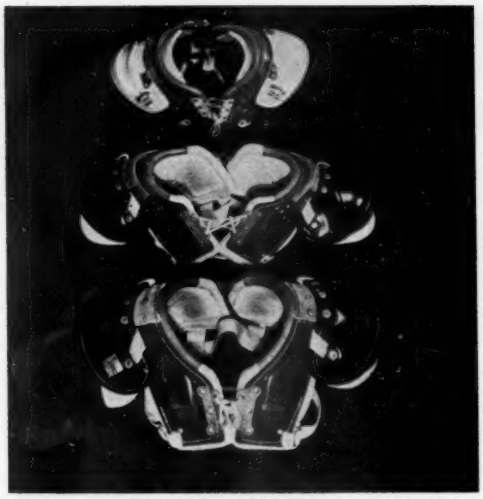

FIG. 2. Types of shoulder pads used at Cornell University. Top, light inside cantilever pad. Arrows point to inside cantilever bridge (Ensolite). The other parts are composed of a central fiber layer coated completely by Ensolite, the "sandwich" construction. Middle, outside cantilever pad of fiber-leather construction. Arrows point to cantilever bridge applied external to body of pad. Bottom, flat pad of fiber-leather.

In spite of the efforts involved in producing shoulder pads that provide protection, injuries to the shoulder, usually of the nuisance type, occur with some regularity. In some instances the shoulder pad itself, especially when it confines at the neck preventing free mobility or when its inner edge is driven into the root of the neck, contributes or actually causes injury to a nerve. In other instances a movable part, such as the epaulet, temporarily exposes the shoulder to injury. To what extent the entire pad restricts free mobility of the neck and arms, thus contributing to injury, is an unanswered question. The lighter, newly introduced, closed-cell foam plastic pads allow for greater mobility of the neck and shoulder, and it will be interesting to see whether the incidence of injuries

* Featherlax Corp., Houston, Texas.

* Ensolite® M2266 (U. S. Rubber Co.) is the material used at Cornell University.

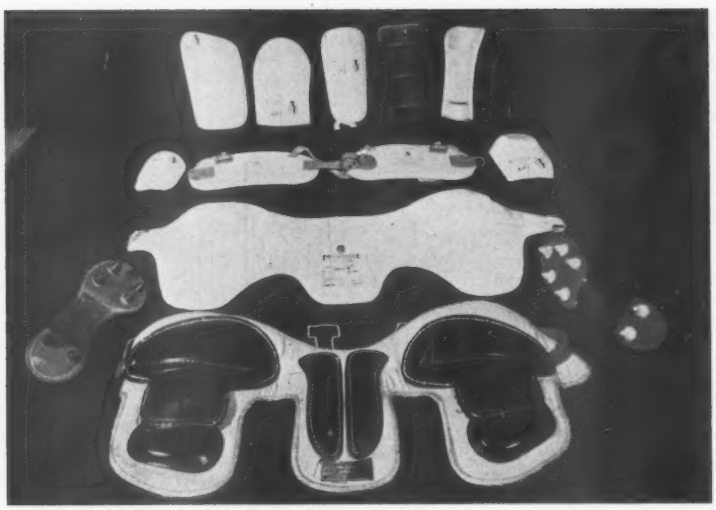

FIG. 3. Types of smaller pads. Top row (left to right), thigh, knee, shin, shin (obsolete), forearm. Second row from top, general utility ("injury" pad), ribs, hand (dorsum). Bottom row, in foreground, obsolete hip pad of fiber-leather. Above it, new light Ensolite pad. Shoes show rubber cleats on left, nylon cleats on right.

to the shoulder and neck will decline. Unfortunately, the present crop of linemen prefer the fiber pad for blocking purposes because of the feel of finality that comes with a well executed block, a sensation not experienced with the lighter plastic pad.

After many years of experience with fiber pads, the staff at Cornell University long ago settled on the use of the outside cantilever shoulder pad. It has been believed that it provides a better distribution of the blow and is less prone to cause injuries to nerves and soft tissues than the inside cantilever pad of fiber construction. On the other hand, no deleterious injuries to the shoulder or neck have occurred from limited use of the new light "sandwich" pads with an inside cantilever bridge made of Ensolite. The flat pad providing minimum protection is not used at all.

It is worthy of note that there is a dearth of scientific investigation on shoulder pads of the type done on helmets. Obviously, it is a source of fruitful laboratory research.

THE HIP PAD

The closed-cell foam plastic materials with their light weight and excellent shock-absorbing qualities are ideally adapted for use in the hip pad (Fig. 3), and it will come as no surprise to see it supplant the fiber pad entirely in the future. At Cornell University fiber hip pads are no longer used. When the foam plastic pad has been fitted properly and is worn properly by the player, injuries to the hip have not occurred. On the other hand, in the past with fiber pads injuries above the iliac crest have occurred when the upper edge of the semi-rigid pad was driven into the soft tissues.

THIGH AND KNEE PADS

The thigh pads (Fig. 3), fitting in front pockets of the football pants, are sometimes dislodged with a resultant severe charleyhorse (muscle contusion) in the thigh. It is essential, therefore, that tight-fitting pants be worn and careful attention be given to this detail of fitting. The "sandwich" fiber pad has been found to offer the best protection at Cornell University. As mentioned earlier, the knee can be an extremely dangerous weapon when driven hard against the head of an opponent. It is imperative that baggy pants be avoided so that the pad is kept in position in the pocket over the front of the knee. The foam plastic material used in the knee pad (Fig. 3) should have a minimum thickness of ½ inch.

MISCELLANEOUS PADS

Pads of Ensolite alone or in combination with fiber are used to protect such areas as the ribs,

arms, forearms, the back of the hands and the shins. These pads (Fig. 3) are used generally to protect a part that has been recently injured or an area that is tender from an old injury.

COMMENTS

Because of the frequency of football injuries sustained as a result of poor protective equipment, the physician who handles athletic injuries should familiarize himself with the characteristics of high grade helmets and pads and, when indicated, act in an advisory capacity in their selection and purchase. It should be borne in mind that it is not only false economy to invest in cheap equipment, which testing has shown to be inferior in protective value, but also a misuse of the trust which the young athlete places in those people responsible for his athletic safety.

It is frequently asked if the hard plastic helmet ever serves as an offensive weapon. At Cornell University experience shows that it occasionally causes moderately severe injury to the opposing player. It can serve as a potent weapon when it is used in violation of football rules and is driven deliberately toward the face of the opponent. In such an instance misuse of protective equipment defeats the purpose for which it was designed, and the voice of the medical profession should be raised against this practice whenever it takes place. Of some interest is the practice among Cornell football players of wearing on the helmet an outer panel of foam plastic (Fig. 1) which serves to diminish the impact on the opponent and to protect him to some extent from injury. This philosophy of protecting the opponent as well as the wearer of a given piece of equipment should be encouraged by team physicians. In the foreseeable future, with the increased use of softer but amply protective padding, a significant decline in football injuries can be envisaged. It is hoped that the medical profession will contribute their voice toward achieving this end.

SUMMARY

The subject of protective football equipment is presented based on experience at Cornell University. The laboratory-designed Cornell helmet is described. The one in current use differs from the original model in that the shock-absorbing beam pad is omitted in the former. Current trends in the use of closed-cell foam plastics in the material construction of protective equipment are cited, and a wider use of these plastics which protect both the wearer and the opponent is advocated.

Engineering Research on Protective Headgear

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FROM reports of all kinds of accidents we learn that the human head is among the most vulnerable parts of the human body. In body contact games, such as football, more fatalities are attributed to blows on the head than to any other injury. In any event, a hard blow to the head can be a serious matter. The effect of concussion can remain throughout the lifetime of the athlete.

On a list of important protective athletic equipment for football, protective headgear belongs at the very top.

The analytical evaluation and treatment of trauma is one of medicine. The mechanics of preventing the blow and reducing its detrimental effect on the head is one that challenges the engineer. A joint approach in which knowledge of "what goes on inside the head" complements "what goes on outside the head" should be the most effective.

Fourteen years ago work began on the engineering side of this head protection problem. During the intervening years projects have been sponsored at Cornell Aeronautical Laboratory, Inc. by several branches of the federal government such as the Office of Naval Research, the Quartermaster Corps and the Air Force, as well as the state of New York. Industry contributed by sponsoring research on padding materials and the development of protective headgear for all sorts of uses including football. Our extensive research on automobile crash safety also contributed greatly to the knowledge of impact blows to the head.

Some of the questions that required answers were: How much head protection is needed or should be provided? How can the value of protection be measured? What should be the physical form and construction of the practical headgear?

I do not intend in this short article to go into the details of laboratory technics, of instrumentations and helmet engineering design procedures. However, it should be mentioned that head blows received in football play are of very short duration, and laboratory impact data was, therefore, measured through electronic instrumentation.

During studies of impact blows to the helmet, measurements were made of acceleration of the head form, fluid pressure in a simulated brain fluid, pressure intensity on the head form in line with the blow, stresses in material of the simulated head form, energy received and initial impulse at the instant of contact.

A study was made of motion pictures taken of football games to determine the magnitude and type of blows which a player might expect to receive. Several scenes were uncovered in which players ran into each other at high speed, hit the ground at high velocity or were thrown backward from a standing position. These pictures were analyzed, frame by frame, and an order of magnitude of the energy of the blow determined. It appeared that blows no greater than 1,100 inch pounds (equivalent to a 10 pound weight dropping 110 inches) are to be expected in an ordinary football game. These blows compare closely with those obtained when the "thin man" dummy was used during a study for the New York State Athletic Commission. The Athletic Commission protection project was directed toward reducing the hazard to the head when it strikes the mat during a boxing contest.

The blow to the head can be from any direction. However, the harder blows most often occur in the sagittal plane, from the forehead to the back of the head. Some degree of protection from transverse blows to the side of the head is afforded by the projecting shoulders.

A large number of helmets for football

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players, pilots and industrial workers were made available to Cornell Laboratory for tests. Most of these helmets fell into two general classifications: (1) those in which the head was held in position within the hard shell of the helmet by padding materials, and (2) those in which the head was held in position by a strap suspension system. A few of the helmets combined these two principles of head support. Helmet shells were made from many materials ranging in stiffness from comparatively flexible rubber-like plastics to stiff phenolic-bound fiberglas or steel. Leather and vulcanized fiber are also common shell construction materials. It was found that, in general, the helmet shell was quite stiff as a structural member under blows from the top (in the dome direction). However, many helmet shells (including all football helmet shells) were quite flexible in the ring direction, offering very little resistance to blows around the equator.

It was found that very often blows in the equator or ring direction tended to flex the shell into the head and deliver the blow in a localized manner. The common padding or strap system used to suspend the head in the shell contributed very little to stiffening the helmet shell itself against this internal bending.

Throughout the years several measurements have been made in an attempt to determine the danger to the head from blows received through protective headgear. They were: peak acceleration to the head, pressure in the simulated brain fluid, intensity of pressure over the skull, strain in the head form, rate of change of accelerated, initial impulse, total force and energy of blow received by the head form. If all these measurements are low, the helmet is good. The exact relative values are as yet undetermined.

In our various reports on the subject, these data have been carefully recorded as comparison information—helmet with helmet. An extensive program of carefully controlled medical research, similar to that conducted by Dr. Gurdjian of Wayne University on cadaver heads, will be necessary to correlate properly the relative importance of each of the effects.

Based on experience with simple egg-like objects (plastic head forms filled with simulated brain fluid), we are led to believe that three important measurements are: the magnitude of total force received through the helmet by the head, the distribution of the force by the helmet on the head and the amount of energy absorbed by the helmet.

In other words, it would appear that the best headpiece for protecting the football player will be the one that will best reduce the magnitude of the blow by absorbing some of its energy and then distributing the force received by the head as uniformly as possible. It must, of course, prevent laceration and abrasion to the scalp.

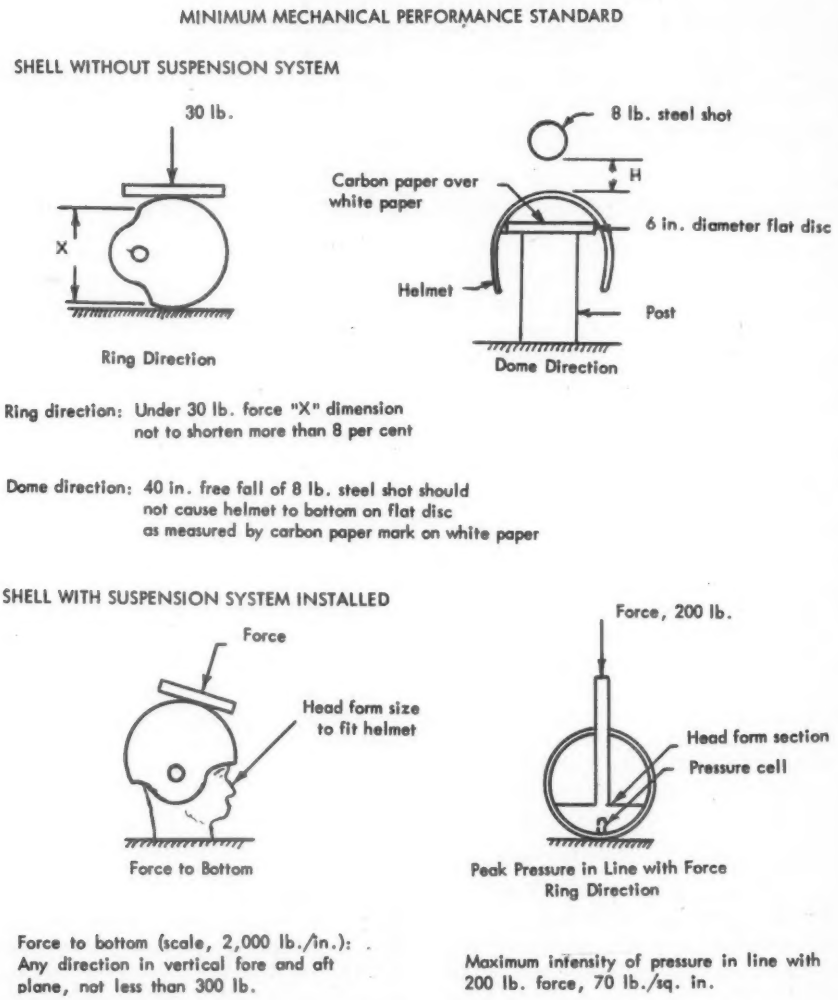
If the weight and size of the helmet are not considered, it is not too difficult to design a helmet to protect the head against blows that would break the neck. However, it is a difficult engineering problem to design a headpiece of acceptable size and weight that will give the needed protection. The upper limit of acceptable weight for football use appears to be about 2 pounds, and the upper limit of size corresponds to a projection of about ¾ inch from the head in the horizontal direction and 1½ inches in the vertical direction.

The shell must be of such a material and shape as to prevent denting in under blows from any direction and making contact with the head. When a helmet "bottoms," most of the protective value against impact blows is lost, and the full force of the blow is concentrated on the head under the dent. In other words, the shell itself must be very stiff or it must somehow receive a stiffening effect from the interliner.

The suspension system (the straps, padding, etc. that hold the head within the shell) should be of such design, material and construction as to prevent the head from moving toward and contacting the shell. Also, the suspension should distribute the force of the blow over the head in a uniform manner. For best results the helmet shell and the helmet suspension system must be considered as companion designs.

The stiffness of the helmet shell in any one direction can be obtained by using a stiffer material (higher modulus of elasticity), by increasing thickness or by changing shape. For example, a high crown, using the same kind and thickness of material, would be stiffer in the vertical direction than a low crown. The padding and/or strap system commonly used in the suspension contributes little or nothing at all to the stiffness of the shell.

The head suspension system can be divided into two component parts, one controlling the motion of the head in the vertical or inclined direction (dome action) and the other acting in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X
Ring Direction
8 lb. steel shot
H
Carbon paper over white paper
6 in. diameter flat disc
Helmet
Post
Dome Direction
Ring direction: Under 30 lb. force "X" dimension not to shorten more than 8 per cent
Dome direction: 40 in. free fall of 8 lb. steel shot should not cause helmet to bottom on flat disc as measured by carbon paper mark on white paper
SHELL WITH SUSPENSION SYSTEM INSTALLED
Force
Head form size to fit helmet
Force to Bottom
Force, 200 lb.
Head form section
Pressure cell
Peak Pressure in Line with Force
Ring Direction
Force to bottom (scale, 2,000 lb./in.): Any direction in vertical fore and aft plane, not less than 300 lb.
Maximum intensity of pressure in line with 200 lb. force, 70 lb./sq. in.

FIG. 1.

the horizontal direction (ring action). The combined action of these two parts should prevent the head from making contact with the helmet shell, and should do so by distributing the resisting force uniformly over the surface of the head.

The conventional strap suspension system (general configuration similar to meridians of longitude), which has been commonly used as the dome direction component, is unidirectional. The protection is good for top blows since the helmet shell is strong in this direction and the straps stretch very little. However, the protection is poor from angle blows since the geometry of the straps is such as to allow the helmet shell to move easily in relation to the head.

Padding systems permit the head to move toward the shell by compressing the padding material. The resulting blow to the head is delivered in a localized manner, in line with the dent in the shell, and thus only a small area of the padding material is effective in resisting the motion.

Strap systems, in the plane of the sweatband (referred to previously as the ring direction), are not very effective in reducing impact blows to the head. The shell flexes easily with low resisting force and moves in to "bottom" on the head.

The Cornell Aeronautical Laboratory solution to the problem of suspension in the dome direction was to use a "geodetic suspension system," and arrangement of support straps. In this system each strap follows the path of a great circle but not over the pole. This arrangement provides a geometry of straps to resist inclined blows as well as vertical blows.

The laboratory solution to the problem of the suspension system in the ring direction was to use a patented arrangement of padding and cloth attached to the shell in a manner both to stiffen the shell in this direction and to cause the blow transferred through it to be wrapped around the head in a more uniform manner. This system of cloth and padding material attached to the shell in such a manner as to distribute the load as a beam and at the same time pad the surface is called a "beam pad." One of the new types of padding materials, Ensolite,® a product of the U. S. Rubber Co., is used in the beam pad. These two systems now patented, were developed under a contract supported by MacGregor Sports Products, Cincinnati, Ohio.

The Cornell helmet has been in use for several years with excellent results. However, it has not been used extensively because: (1) It cost more. (2) It does not feel as comfortable when first used as other helmets. It requires a short period of breaking-in, like a new pair of shoes. (3) There have been several cases of broken helmet shells. The improved suspension system has forced the helmet shell to take the stress rather than the head.

During this discussion we have been devoting all our attention to protecting the player who will be wearing the helmet. Since football is a competitive athletic sport, not a war, we must also consider reducing the injury potential for the other fellow. A layer of Ensolite on the outside of the hard shell is a step in the right direction for softening up the exterior of protective athletic equipment.

There are many ways of designing and building good protective headgear. It is not so important how it is done as that it is done.

So far as I know, at present there are no recognized specifications or standards which control protective headgear for football. Each brand is now sold on the basis of color, cost, softness, flexibility or any other sales "gimmick."

To raise the quality of any device it is necessary first to set up minimum performance standards which must be met. Sales will then more often be made on how well the product meets or exceeds the performance specifications.

At the request of the chairman of the American Medical Association Committee on Sports Injuries, in June 1957 I prepared a set of recommended minimum performance standards for protective headgear. (Fig. 1.)

RECOMMENDED MINIMUM STANDARDS FOR PROTECTIVE HEADGEAR FOR BODY CONTACT GAMES*

(Based on Research Conducted at Cornell Aeronautical Laboratory, Inc.)

The objectives of a good protective helmet are to:

1. Reduce the magnitude of the blow to the head.
2. Distribute the remaining force received by the head over as wide an area as possible.
3. Prevent lacerations and abrasions to the scalp.

To accomplish these objectives, the helmet must be of such a material and shape as to prevent the shell from denting in to make contact with the head. The material should also be highly resistant to abrasion, scoring and cracking.

The suspension system (the straps, padding, etc. that hold the head within the shell) should be of such a design, material and construction as to prevent the head from moving to make contact with the shell. Also, the suspension should distribute the force of the blow over the surface of the head in a uniform manner.

* Editor's note (T. B. Q.): These minimum standards, among others, are under consideration by the Committee on Injury in Sports of the American Medical Association. No official statement or recommendation has yet been made by this Committee. See "Organized Medicine and Athletics: The Role of the American Medical Association Committee on Injury in Sports" by Dr. Allan J. Ryan, page 325.

DEFINITION OF CORNELL AERONAUTICAL LABORATORY'S MINIMUM STANDARDS

Force to bottom: The force in pounds applied as a flat surface to the outside of the shell when the deflection of the shell under the force reaches 2,000 times the deformation measured in inches: $F = 2{,}000 \times \text{def}$.

Intensity of pressure: Pressure on the head form in pounds per square inch.

These mechanical performance tests can be performed quite easily by any company in the helmet-manufacturing business. They do not dictate how the helmet or shell shall be made or the material of which it is to be made. The standards are low enough so that most of the reliable manufacturers will have no trouble in meeting and exceeding them.

It is strongly recommended that these minimum standards, or some standards, be set up to bring about needed improvements in protective headgear for football. A start must be made to increase safety on the football field.

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Experimental Investigations of Ligamentous Healing

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Following severe injury with complete rupture of a ligament, instability of the joint often occurs because the ligament fails to heal with proper length and strength. Most of the clinical interest in the problem has centered about the knee and ankle, since they are particularly vulnerable to ligamentous injuries.

The classic method of initial therapy has been rest and immobilization [*5*], usually by plaster cast, followed by exercise of the affected joint. Recently several reports have advocated early operation to suture the torn ligament [*1,4,9, 11–15*].

REVIEW OF PREVIOUS EXPERIMENTAL INVESTIGATION

In 1937 Miltner, Hugh, and Fang [*11*] produced sprains in the knees and ankle joints of rabbits. Mild sprains were produced in twelve, severe sprains in eleven. There was no evidence of bony injury on x-ray examination. The animals were sacrificed at intervals and the specimens examined grossly and microscopically. The animals were not immobilized. Attempts were made to determine the effects of immobilization on the rate of healing but, since it was difficult to maintain satisfactory immobilization by plaster, the results were discarded.

Pathological changes after a mild sprain at the end of one week revealed edema, fibroblastic proliferation, and infiltration with lymphoid cells in the injured ligaments and capsule near the bony attachments. There were similar changes in the synovial tissue with an increase in the joint fluid and evidence of hemorrhage into the subcutaneous tissues. Two and three weeks after sprain there were still signs of acute inflammation of the synovial tissue and a great increase in fibroblasts in the soft tissues surrounding the ligament and capsule. At four weeks there were no remaining gross external signs, but ligaments and synovia still revealed microscopic signs of old hemorrhage, few fibroblasts, more collagen fibers, and less infiltration with leukocytes and lymphoid cells. At six weeks, healing was complete with a late stage of fibrosis, and with shrinkage and contracture of the structures of connective tissue.

In addition to the aforementioned changes, the severe sprains revealed a fibrillar degeneration of the surface layers of cartilage, especially at the margins of the joint surfaces on the affected side; there was also definite evidence of a tearing injury at the point of insertion of ligaments to bone. The process of repair persisted for eight to ten weeks. In this series we do not know if the ligaments were completely ruptured.

In 1950 Jack [*7*] produced complete ruptures of the medial collateral ligament of the knee in cats. The joints were immediately explored to determine the extent of injury; deep structures were not sutured, and the wounds were closed but not immobilized. In every instance, the ligament ruptured along a definite line, without detachment of bone flakes; rupture occurred at the upper end seven times, lower end six times, and there were six cases of a long oblique tear. The ends of the ligament always recoiled, and in the transverse tears a wide gap was frequently found with the body of the ligament curled up and under the areolar sheath; with displacement the ligamentous tissue became lost

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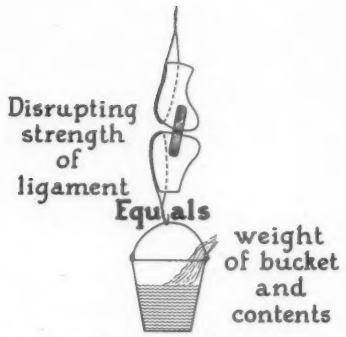

FIG. 1. Method of testing tensile strength.

in a mass of irregular scar during the healing process (between one-third and one-half of his cases). When conditions were favorable and the ligamentous ends were not widely separated, the torn ligaments healed in the manner described by Mason and Shearon [*8*] in 1932 in injuries to tendon. The ruptured gap fills with blood. Proliferation of cells from loose areolar tissue quickly converts the clot into granulation tissue. There is an increase in vascularity of the ligamentous ends, and after four to five days proliferation of the ligamentous cells begins with formation of new collagen fibrils. Cells and fibrils migrate from the torn ends into the granulation tissue until the gap is bridged by collagenous tissue. After two weeks, granulation tissue is replaced by parallel collagenous fibers of immature type continuous with original ligamentous fibers. After three weeks, cells and blood vessels diminish in number, while collagenous fibers increase in size and strength and begin to assume arrangement into bundles. At seven weeks the gross ligament appears virtually normal except for slight local thickening. This process represents healing by regeneration of regular collagenous tissue from the ligamentous fibers so that continuity is restored.

In these experiments the gross and microscopic findings after sprains and complete ruptures of ligaments have been presented; but there has been no suture of the ruptured ligaments, no immobilization, and no determinations of the tensile strength of the healing tissues.

The purpose of this paper is to compare the tensile strength and microscopic picture of divided ligaments treated by simple immobilization and by suture.

TABLE 1

TENSILE STRENGTH OF THE MEDIAL COLLATERAL LIGAMENTS IN TEN NORMAL DOGS

Weight of Dog (kg.)	Tensile Strength (kg.)		Difference (kg.)
	Right	Left	
7.3	6.4	6.1	0.3
7.7	7.4	7.3	0.1
7.9	6.8	6.4	0.4
8.2	11.5	10.7	0.8
9.8	13.7	15.0	1.3
10.2	7.8	7.3	0.5
15.5	13.8	14.9	1.1
17.4	12.4	12.8	0.4
23.2	16.5	16.3	0.2
27.0	9.9	10.1	0.2

MATERIALS AND METHODS

Thirteen adult mongrel dogs were used in this study. With the animal under general anesthesia (Pentothal®), bilateral, left and right, parapatellar incisions were made and the medial and lateral collateral ligaments of the knee exposed.

Because preliminary work had shown that it was impossible to rupture the ligaments by manual force and obtain a uniform lesion, the ligaments were horizontally transected with a scalpel at the joint line. The cut ends were examined to make sure the ligament had been completely transected. In one leg the ends were approximated with three stitches of No. 000 silk; in the other the ends were allowed to lie as they chose. The legs were immobilized in 10 to 15 degrees of flexion by a Steinmann pin drilled into the femur and then drilled retrograde through the knee joint into the tibia. The fascia and skin were closed, using an identical technic on each side.

At periods of four days and one, two, three, four, six and nine weeks postoperatively, dogs were sacrificed by an overdose of Pentothal. The lateral collateral ligaments were removed *en bloc* with a small portion of the surrounding soft tissues for microscopic study.

After removal of the lateral collateral ligament, tensile strength was measured on the medial collateral ligament. All structures connecting the femur and tibia, except the medial collateral ligament, were removed from the specimen. The sutures were left in the sutured

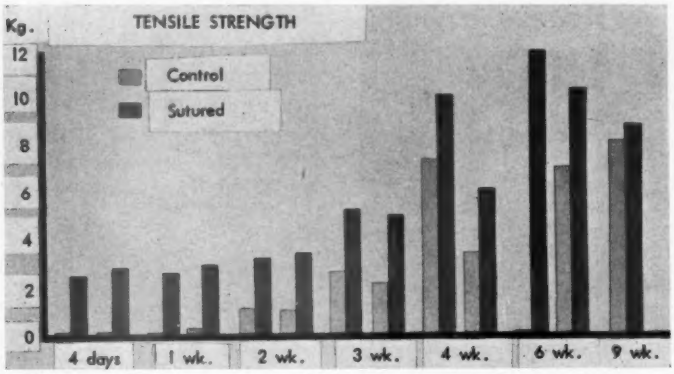

FIG. 2. Results of the determinations of tensile strength in the experimental animals. (The control is the unsutured ligament.)

ligament. The ligament with a 4 cm. portion of bone at each end was removed, and a wire placed through a drill hole in each bone. One wire was hung to the ceiling, the other attached to a bucket which was rapidly filled with water until the ligament broke. (Fig. 1.) The bucket and contents were then weighed and this value was used as the tensile strength of the ligament.

RESULTS

Tensile Strength. Table 1 shows the tensile strength of the medial collateral ligaments in ten normal dogs. In each of the twenty tests the ligament was torn from the tibial insertion, often by pulling away a flake of bone, so that the figures are not absolute values of ligamentous strength but merely a base line at which the experimental values may be compared. There is a marked variation between dogs, but no appreciable variation between right and left legs in the same dog. Therefore, comparisons between dogs would not be valid, but tensile strength in the right and left legs may be compared in the same dog.

Figure 2 shows the determinations of tensile strength in the experimental animals. It is evident that the sutured ligament was stronger in every case. Separation in those dogs sacrificed in the first four weeks postoperatively occurred at the line of incision, in both the sutured and unsutured control ligaments. Since all of the normal ligaments pulled away intact from the tibial insertion, it is evident that the original strength is not recovered in four weeks. After six weeks no suture line could be disrupted—at six weeks both ligaments parted through the ligamento-osseous juncture; at nine weeks the ligament parted through an area of normal ligament proximal to the suture line. This would indicate that the sutured ligament has regained a functionally normal strength by six weeks, as the line of division is no longer the "weakest link in the chain." At six weeks one of the unsutured ligaments failed to heal (Fig. 3); this ligament had no measurable tensile strength and no infection was noted. It is possible that areolar tissue enveloped the ends of the ligament and prevented the healing process. In the other dog sacrificed at six weeks and the dog sacrificed at nine weeks, the unsutured ligament disrupted at the line of incision, a new "weaker link" in the chain.

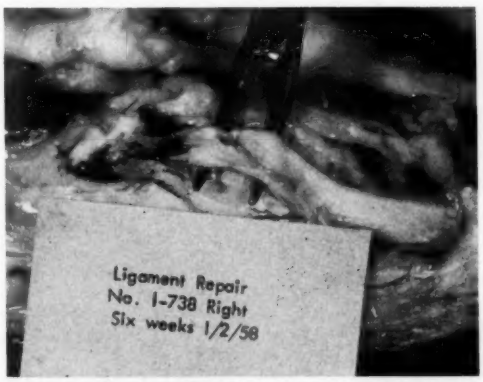

FIG. 3. The unsutured ligament at six weeks presents a very definite gap in which the ends appear to be rounded and there is no linking of the two ends. There was no measurable tensile strength. This ligament seemed to show a complete failure to heal.

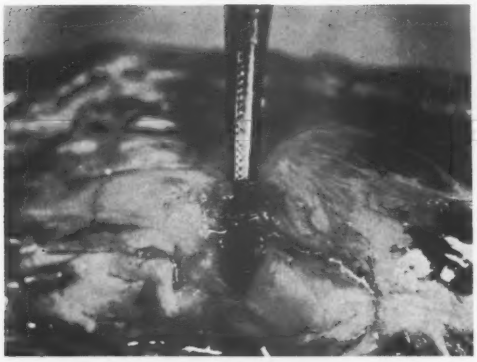

FIG. 4. Unsutured ligament at four days. Note the gap in the ligament which is filled with blood clot.

FIG. 5. Unsutured ligament at two weeks. The gap is still present and is filled with thin, transparent, grayish tissue.

FIG. 6. Unsutured ligament at six weeks. There is still a definite gap filled with different, slightly grayish, tissue.

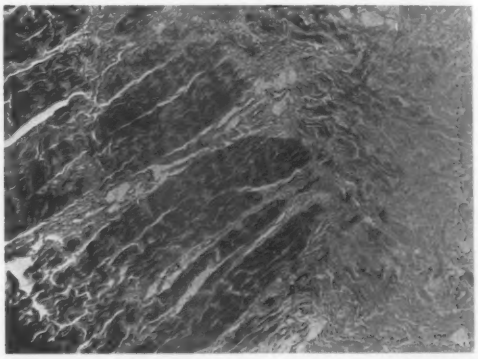

FIG. 7. Horizontal section of an unsutured ligament, six weeks postoperatively, taken through the line of incision. Note the rounded ends of the ligamentous fibers, which then give way to fibrous tissue. Original magnification, × 25.

FIG. 8. Sutured ligament at four days. (Same dog as in Figure 4.) The ligament is intact and no gap can be seen.

FIG. 9. Sutured ligament at two weeks. (Same dog as in Figure 5.) There is no gap in the sutured ligament. Note the increased swelling present at the suture line.

FIG. 10. Sutured ligament at six weeks. (Same dog as in Figure 6.) There is no gap in the sutured ligament and it has a grossly normal appearance.

FIG. 11. Sutured ligament at six weeks. (Same dog as in Figure 3.) The sutured ligament is well healed with no gap.

Gross and Microscopic Results. In the unsutured ligaments the gap appeared to be filled with a blood clot on the fourth day. (Fig. 4.) The blood clot was gradually converted into fibrous tissue. (Fig. 5.) There was some growth of ligamentous fibers into the fibrous tissue, but a considerable gap of scar tissue still remained at six and nine weeks. This was visible, both grossly and microscopically. (Figs. 6 and 7.)

In the sutured ligaments the suture line was intact in every instance, with no visible separation. (Fig. 8.) There was considerable swelling of the ligament near the suture line, maximum at about the two-week period (Fig. 9), and at six weeks the suture line appeared to be well healed, both grossly and microscopically. (Figs. 10 through 12.) The microscopic sections of the unsutured ligament at six weeks showed the ends to be rounding off in a mass of fibrous scar tissue. (Fig. 7.) In the sutured ligament no definite break could be noted in the ligamentous tissue at the suture line. Minimal scar tissue was noted in the area. (Fig. 2.)

All the unsutured ligaments revealed a gap, although there was no obvious separation at the time of division and immobilization.

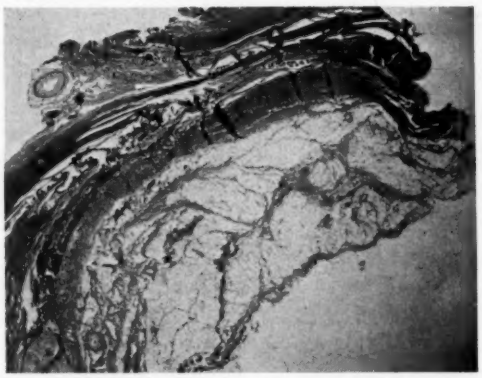

FIG. 12. For comparison, this is a longitudinal section of the sutured ligament from the same dog as in Figure 7. No definite break in the ligamentous tissue can be seen. Minimal scar tissue is present.

COMMENTS

We believe that the fibrous tissue filling the gap in the unsutured ligaments creates a weak link in the ligament, as indicated by the determinations of tensile strength. In the sutured ligaments the cut ends are approximated and the ligamentous fibers reunite, with no demonstrable gap on gross and microscopic examination. The sutured ligaments have sufficiently recovered their strength at the end of six weeks to make the weakest point the ligamento-osseous juncture, as it is in normal ligaments.

CONCLUSIONS

1. Ligaments which have been divided and immobilized heal with a gap of fibrous tissue between their cut ends.

2. Ligaments which have been divided and have had the cut ends approximated by suture heal by union of the ligamentous fibers without a gap.

3. Sutured ligaments are stronger at all test periods than unsutured controls.

4. After six weeks the suture line cannot be

disrupted, as the ligament parts through a normal area. The suture line is no longer the weakest link in the chain.

5. For a period of nine weeks all unsutured ligaments disrupt through the line of previous section. The line of division is still the weakest link in the chain.

Acknowledgment: We wish to acknowledge the assistance of Dr. Ben Eiseman in planning this experiment.

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Initial Management of Athletic Injuries to the Head and Neck

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PROFESSIONAL teams, college athletic departments and large high schools usually have team physicians who evaluate all injuries. However, grade school teams, small town high school teams and unorganized sand-lot teams have no regular physician and when members of these teams are injured, their injuries are evaluated first by the family physician. These team and local physicians are, therefore, obligated to have a working knowledge of what constitutes adequate initial evaluation, as well as the continued observation of the patient who has sustained injury to his head or neck. Equally important is the determination as to when the injured athlete may safely resume athletic participation. Since this medical decision must be made by the team or local physician rather than by a coach or athletic trainer, it is to these two groups of physicians that this communication is primarily directed.

Excellent comprehensive reviews have been published regarding the frequency, type and severity of injuries, with discussions of factors relating to cause and prevention [*1,2,6,7*]. Hibbert [*4*] reviewed data on 46,824 high school athletes from four representative states for a one-year period. He found that 20 per cent of these athletes were injured and one in every five of these injuries was serious. Thus, one of every twenty-five athletes can be expected to sustain a serious injury each year. Significantly, athletes in the early teen-age group were five times as likely to be injured as those in the late teen-age group, the more experienced ones. In this and other surveys [*1,7*], injuries involving the head and neck comprise only a small percentage of the entire number of injuries. However, when fatal injuries are reviewed, over 50 per cent of these are the result of trauma to the head or neck [*3*]. Without question the majority of these fatalities can be prevented if injured patients are carefully observed after the injury, if signs of impending disaster are recognized promptly and if definitive treatment is instituted immediately.

The first consideration regarding injuries of any type is that of prevention. The use of protective headgear in various sports, and changes in rules aimed at discouraging unnecessary trauma are valuable preventive measures and detract in no way from the sport itself. Although much has been written about the necessity of a complete medical examination prior to entering competitive athletics [*1*], little can be found in the literature concerning specific neurologic conditions which contraindicate participation in contact sports or when, after an athlete has sustained trauma to the central nervous system, he should be prevented from returning to athletic participation. Thorndike [*8*] reviewed the data on 7,000 athletic injuries incurred during the last twenty years, and suggested four circumstances under which athletes should be barred from further contact sports:

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(1) three or more cerebral concussions; (2) fracture dislocations requiring surgical intervention; (3) viscus injuries requiring removal of the spleen or kidney; and (4) loss of an eye.

A number of neurologic conditions, which may be uncovered while obtaining the athlete's past history and during the physical examination, absolutely contraindicate participation in contact sports and are so obvious that they hardly need mentioning. These are postcraniotomy states, intracerebral aneurysms, vascular malformations, previous fracture dislocations of the spine, and laminectomy for tumor of the spinal cord or ruptured intervertebral disc. Much more troublesome is determining when cerebral trauma constitutes contraindication to participation in contact sports. We find it difficult to agree with Thorndike [8] that three or more cerebral concussions constitute such a contraindication. Actually, this is a highly individualized matter and the severity of the brain injury has to be decided upon in each case. These patients should be studied thoroughly, and if no evidence of damage to the brain is found, we do not believe that they would take any greater risk in engaging in contact sports than other athletes who have not had such injuries [5]. Another troublesome problem is that of a potential athlete who has or has had convulsive seizures. It is our opinion that the majority of such seizures are the result of previous damage to the brain either from trauma or from disease. It is probably wise to recommend that such patients participate in non-contact sports, even if the seizures are well controlled by medication. However, the psychological impact of depriving some athletes of contact sports could in specific cases far outweigh the risk of further injury to the brain, and in these cases it would seem to us that an expert opinion should be obtained. However, in patients who have uncontrolled or incompletely controlled seizures, we believe participation is contraindicated for at least two reasons: if the athlete has a seizure on the field, it might actually be quite dangerous and would certainly be extremely embarrassing.

It is our primary purpose here to outline our concept of the early management of the patient with an injury to the head or neck. A well planned classification and course of action is the most valuable asset with which a team or local physician can be armed when called upon to evaluate and manage a patient with trauma to the central nervous system. For this purpose patients with injuries to the head may be divided into three groups.

The first and by far the largest group is that comprised of athletes who have sustained direct or indirect trauma to the head sufficiently severe to render them momentarily unconscious or disoriented. In order to remain in this group, the injured athlete should completely recover neurologic function, both mentally and physically, immediately following this momentary alteration of consciousness. It must be kept in mind that a small, but significant number of patients later found to have intracranial hematomas sustained only minor trauma to the head. Without question after concussion any patient ideally should be observed by trained medical personnel for twenty-four hours or more. However, because of the frequency of such injuries and the usual uncomplicated course following them, hospitalization ordinarily is not considered necessary by most physicians. *We disagree with this and always advise hospitalization.* Occasionally when the patient, or his parents, refuses hospitalization, we insist on frequent periodic observation of the patient during the next twenty-four hours by some person intelligent enough to recognize any significant change in the patient's condition. A similar regimen should be adopted if there are no hospital facilities immediately available. During this period the patient should be awakened every hour and the observer satisfied regarding the ease with which he may be aroused, the state of consciousness, the equality of the pupils, the normality of the pulse rate, and that there is no dysfunction of one or more extremities. Furthermore, the patient should be questioned concerning headache, visual disturbance, nausea and so forth, and any deviation from normal should prompt re-evaluation by the responsible physician. Even after twenty-four hours it should be kept in mind that signs or symptoms, such as those mentioned, occurring insidiously during the days or weeks which follow are no less significant.

If the injury is uncomplicated, it must then be decided when to allow the patient to return to athletic competition. Not uncommonly a great deal of pressure is exerted on the physician either by the patient himself, the coach or other well meaning friends, to allow the athlete to return to the team immediately. In such a situation the physician must be the sobering

influence and the sole judge as to when it is safe for this athlete to resume play. *In our opinion, even if no untoward symptoms or signs have occurred after twenty-four hours, these athletes should not engage in contact sports for at least one week.*

The second major category includes those athletes whose loss of consciousness is more than just momentary and those who are slow to clear mentally. *This at the very least means some degree of contusion of the brain.* Nausea and vomiting, persistent headache, unsteadiness or any transient neurological deficit in addition to loss of consciousness are definite evidence of more severe injury to the brain. All such patients should be hospitalized. Roentgenograms of the skull should be taken and periodic examinations should be carried out by capable nursing or house staff personnel. The state of consciousness, pulse rate, respiratory rate and blood pressure should be checked every fifteen minutes until stable and then every hour for twenty-four hours or longer if necessary. Any deviation from normal or deterioration in the state of consciousness, increasing drowsiness or disorientation, dilatation of one pupil, increasing motor or sensory deficit, or cranial nerve dysfunction should prompt emergency neurological consultation. *If, on the other hand, recovery is uncomplicated, it is our opinion that such athletes should refrain from participation in any type of sport for at least two weeks.*

The patients who comprise the third major group include athletes who remain unconscious, those with depressed or compound skull fractures with or without gross neurologic deficit, and those who have progressive neurologic signs. The need for hospitalization in these cases is obvious. The most frequent error made in the management of these more serious cases is the hesitation to move such patients to neurosurgical centers. It is our conviction that the only real contraindications to moving such a patient immediately are shock from blood loss, persistent bleeding which should be controlled, or acute respiratory difficulties which might demand emergency treatment prior to moving. Of prime importance is the management of unconscious patients during transportation. A patent airway is an absolute necessity and one of the cardinal rules in the care of any comatose patient is that he be kept off of his back. These patients should be maintained on their sides with the head and particularly the corner of the mouth dependent. The twofold purpose of such a position is to prevent obstruction of the oropharynx and to allow secretions and vomitus to drain from the mouth, thus preventing aspiration. The second essential rule is to refrain from administering narcotics or sedatives. Narcotics not only depress respiration, but at times cause definite increase in intracranial pressure as well as altering the state of consciousness and pupillary signs which are so important in the evaluation and subsequent observation of the patient.

With modern methods of treatment, the prognosis following more severe injury to the head has definitely improved. *It is our conviction that no matter how complete recovery may seem, the patient's further participation in contact sports should be prohibited.*

In our experience cervical spinal injuries of serious consequence are rarely sustained by participants in contact sports. However, in our community fracture dislocations of the cervical spine with damage to the spinal cord result more frequently from diving accidents than from any other type of injury. We are convinced that the public is totally unaware of the risks inherent in diving and we know of no way to combat this ignorance except through wide publication in the press. We are at a loss to suggest ways of preventing injuries to the neck in other sports except by strict enforcement of existing rules.

As every physician knows, when the spinal cord is severed function cannot be restored. As a matter of fact, when the spinal cord is damaged, little if anything can be done to restore function. Ultimate recovery usually depends on how badly the cord has been damaged. *However, once an injury to the spinal cord has occurred, it is imperative that steps be taken to prevent additional damage.* This is the prime consideration in the treatment of such injuries. Only rarely have we seen progressive loss of function below the level of the lesion following injury to the cervical spinal cord which did not result from improper movement or manipulation of the patient. Under such uncommon circumstances one should suspect an intraspinal hematoma and this, in our judgment, constitutes the only realistic indication for laminectomy in these cases. We admit that in the presence of an injury to the spinal cord with total loss of function and a complete block of the spinal, subarachnoid space, laminectomy is

thought to be indicated by many neurosurgeons. However, we are by no means convinced that such an operation has ever contributed to the recovery of a patient with such an injury.

On the other hand, we are not as pessimistic about the recovery of function of the nerve root following operation. Damage to the nerve root may result from direct trauma, soft tissue or bony compression, or from rupture of the cervical disc, and may represent the only neurologic deficit in many injuries to the cervical spine. It may occur in conjunction with injury to the spinal cord, and in such cases the preservation or restoration of function of one cervical nerve root, depending on the level, can mean the difference between a useful limb and a comparatively useless one.

Intraspinal ruptures of cervical discs with classic neurologic deficits are extremely rare prior to the age of thirty years, and we have never seen one resulting from athletic injury. However, there is no doubt that in such cases conservative treatment with traction is usually a waste of time and removal of the extruded fragments is necessary to obtain relief of pain and restoration of function.

In a patient who has sustained an injury to the cervical spine, the clinical picture confronting the physician may vary between marked extremes. A person may present himself immediately with pain and stiffness in the neck, or days or weeks later, having temporarily disregarded the injury and continued playing. We have been amazed at the number of patients we have seen who complained chiefly of a crick in the neck following an apparently trivial injury to the neck and who were proved to have fracture dislocations of the cervical spine without neurologic deficit. At the other extreme is the athlete still on the athletic field or at the pool side completely quadriplegic. Any patient who upon initial examination shows signs or symptoms suggestive of spinal injury should be treated as having a fracture dislocation until proved otherwise. Physicians and the public for the most part are aware that such patients need the utmost care in transportation and movement.

Patients with spinal injuries, like those with injuries to the head, may be divided into three major groups. The first consists of patients who have no evidence of neurologic deficit and simply complain of pain or stiffness in the neck. All such patients should have roentgenograms taken of the cervical spine and these films should be considered inadequate unless all cervical vertebral bodies are visualized on both the anteroposterior and lateral projections. Adequate lateral views are particularly difficult to obtain, especially in a person with considerable pain and muscle spasm; it is frequently necessary to exert simultaneous traction on the head and downward traction on both arms while roentgenograms are being made in order to visualize the lower cervical vertebrae on lateral films. Open mouth views may be necessary to demonstrate the odontoid.

If a fracture or dislocation can be ruled out, conservative symptomatic measures are the only treatment recommended. Athletic participation may be resumed in most instances when a full range of motion in the cervical spine can be carried out without pain and when muscle spasm has subsided. Not infrequently in this group of patients with injury to the cervical spine the roentgenograms reveal a definite reversal of the normal cervical curve. This may persist for periods varying from days to years. The exact significance of this change is not completely understood, but without question most of these patients have more persistent symptoms following the injury and a significant number are seen in later years with symptoms consistent with degeneration of the cervical disc and roentgenographic evidence of narrowing of the discs and/or vertebral body spurring. Whether or not these athletes should be prevented from returning to contact sports is a question we are not prepared to answer. Up to the present time no adequate long term studies have been carried out on such patients.

The second major group is comprised of those patients who have experienced minimal to moderate neurological deficit, such as weakness or numbness of one or more extremities. Not infrequently this initial paresis may clear to some extent or completely disappear following a short period. Such injured athletes should be moved by stretcher directly to medical centers where complete evaluation can be carried out and proper treatment instituted. They should not be subjected to unnecessary movements for any purpose including the taking of roentgenograms until supervised by trained personnel. Athletes who have proved fracture dislocations of the cervical spine and those who experience transient or persistent symptoms of nerve root compression are most safely trans-

ported in the supine position with head halter traction applied, using 5 to 10 pounds of weight. In the event traction apparatus is not available, sand bags should be applied to the side of the head and neck to prevent lateral or rotary motion. It is hardly necessary to add that an attendant should be with the patient constantly to see that no movement of the head or neck occurs.

Athletes in this group have sustained significant injury to the cervical spine even though at times a roentgenographic abnormality may not be evident. *Although recovery may be apparently complete, these athletes should be probibited from further participation in contact sports and diving.*

Those athletes in whom paraplegia or quadriplegia is present from the onset comprise the third group. The need for hospitalization is obvious and the precautions already outlined for transportation to such centers should be employed. The prognosis for recovery of function in these patients is extremely poor and, as stated, any function of the spinal cord or nerve which can be preserved will prove invaluable. No tragedy can compare with the sudden catastrophic transformation of a young active athlete to a helpless permanent quadriplegic. The vast pathetic problem of prolonged rehabilitation, both psychological and physical, will demand the combined effort of family, physician and friends.

SUMMARY

Over half of the fatal injuries sustained by athletes result from trauma to the head and neck. Any significant reduction in the mortality rate following athletic injuries to the head must begin with the team or family physician. Only through the physician's acute awareness of his responsibility in the detection of the symptoms and signs which suggest impending disaster, and the institution of emergency treatment when indicated, can these fatalities be avoided.

In injuries to the cervical spine with damage to the spinal cord or nerve root, the primary responsibility of the team or local physician is the prevention of additional neurologic damage. The precautions regarding movement and transportation of these patients must be rigidly enforced by the physician who institutes the initial management of these injured athletes. The period of time which should elapse following specific injuries prior to resumption of athletic competition and the injuries which constitute definite contraindication to contact sport activity are discussed.

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Injuries to the Eye

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SERIOUS injury to the eyeball or periorbital structures is not a common occurrence in most forms of athletic activity. In fact, the literature is rather sparse, and what references there are relate chiefly to boxing [1,2]. In this sport a deliberate attempt is frequently made to inflict damage to the eyelids in the form of lacerations, edema and hematomas. The resulting edema can incapacitate a boxer to the point at which his opponent can win by a technical knockout. Although it is not the conscious plan of the attacker to injure the internal structures of his rival's eye, this not infrequently happens. In no other sport is there a deliberate attempt to damage an opponent's eyes.

Although in other types of athletic activities serious ocular injury is rather rare, nevertheless, when it does occur, it can be a major catastrophe.

In general most ophthalmic injuries are due to the application of force (usually blunt) in one manner or another to the eye and surrounding orbit, the resulting injury differing little, if at all, from those encountered in other types of physical activity common to industry, war and civil life. Duke-Elder [3] has devoted some 1,200 pages to ophthalmic injuries in his "Textbook of Ophthalmology." These include discussions of chemical and thermal burns, radiation injuries, contusion, concussion, incised wounds and foreign bodies. Although this is a valuable source book for anyone seeking information concerning specific detail, in general the lesions clinically encountered are the result of concussion and contusion. More rarely incised wounds, as from a spiked shoe, and foreign bodies may be a problem.

On first thought, it is rather remarkable that such a delicate structure as the eyeball is not more frequently injured in some of our more rugged contact sports. The fact that it is not is due primarily to its favorable anatomic position. First of all, the globe itself is elastic and can suffer considerable distortion without permanent injury. Secondly, it is imbedded in a resilient fat pad into which it can be retroplaced a considerable distance by the application of external force. This fat mass itself is encased in a bony cavity with overhanging rims, the supra- and infraorbital ridges, which being rounded and thickened can either deflect external force or transmit it to adjacent structures. The size of the opening is relatively small (35 by 40 mm.) so that large objects such as a football or basketball will tend to be deflected before their kinetic force can reach the eyeball. The bony orbit is surrounded, in large part, by the paranasal sinuses, the orbital walls of which are quite thin. When sufficient force is applied to the eyeball, fracture of these walls can, and frequently does, take place. It is usually the medial or inferior wall which yields, allowing the expenditure of force in many directions so that it is not concentrated in the globe. Not uncommonly an eyeball may be displaced downward into the antrum so far as to be totally lost from external view and yet have its visual function undamaged. The zygomatic arch, orbital rims, walls and paranasal sinuses provide a light, yet strong, supporting structure to the orbital content, very much as arches and flying buttresses support the mass of a Gothic cathedral. The optic nerve is considerably longer than is necessary to permit free rotation of the eyeball in the orbit and therefore may be uninjured even though the eyeball may be luxated downward into the antrum or anteriorly through the eyelids.

STANDARDS OF ELIGIBILITY

It is, or course, more sensible to avoid injury than to repair it. Although great strides have been made in the development of protective

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equipment, as witnessed by the now almost universal use of face masks by football teams, improvements can still be made. There are, nevertheless, in spite of the best protective devices, certain individuals who are more prone to ocular injury than others. For this reason certain rather broad standards of physical eligibility have been set by most schools and colleges. Those persons with a high degree of myopia are notoriously subject to retinal detachment. It would be most unwise therefore to allow such individuals to box, high dive, or play football. The exact point at which to draw the line of eligibility, particularly in college and secondary school sports, is difficult to define and may well vary from institution to institution. It is acknowledged that a calculated physical risk must exist in all sports. We accept these risks, weighing as best we can the various factors involved. For some young men athletics is of such paramount importance that prohibition of a sport may have serious psychological repercussions. There are occasions when it is better judgment to take the additional risk, which actually, in most cases, is rather small. An instance comes to mind of a boy of secondary school age, who was an excellent soccer player in spite of having one amblyopic eye. He moved to a new school area where the regulations of the Board of Education prohibited contact sports for those with only one serviceable eye. The boy's school work declined and his social development left something to be desired until as the result of considerable parental influence, the signing of waivers, and the utilization of special headgear, permission was finally granted the youth to take part in this sport. Regulations concerning visual standards are excellent but there are occasions in which it may be wiser not to interpret them too rigidly.

It is usually agreed that those with only one useful eye should not take part in contact sports. This would exclude individuals who have lost one eye from an accident, those in whom profound amblyopia ex anopsia associated with strabismus has developed, and others who from any number of causes may have defective vision. High degrees of myopia, as previously indicated, should be disqualifying but the term "high" is somewhat ephemeral. Certainly myopia of −10.00 diopters would universally be considered in this category. However, −5.00 or −6.00 diopters might be borderline. Here the final decision would have to rest upon competent ophthalmological examination since there are types of myopia exhibiting considerable chorioretinal degeneration in which retinal detachment is more likely to develop. There are other individuals with myopia of equivalent degree who have essentially normal eyes. In these I would be inclined to assume the calculated risk.

USE OF GLASSES

Measurement of visual acuity *per se* is of somewhat dubious value except as a rough guide. Those with less than 20/200 uncorrected vision, or with corrected vision less than 20/20 should wisely be referred for special opinion. If no organic disease is found, the individual, with the exceptions as noted, should be given free choice as to his choice of sports. There is no reason why wearing glasses should be a serious handicap to one engaging in a non-contact sport such as tennis, track, golf, gymnastics, crew, skiing, shooting and the like. Even baseball players can wear glasses satisfactorily. In all these sports, however, the use of non-shatterable glasses should be insisted upon. These may be either in the form of plastic lenses which have the disadvantage of scratching easily, or in the form of case hardened lenses. Many serious injuries to the eye from squash, tennis and golf balls can be avoided if shatterproof lenses are worn.

The use of contact lenses is eminently practical. They are now being worn by many professional and college athletes. Two main types are currently in use (1) corneal lenses which are small discs curved to fit the cornea to which they remain attached by capillary attraction, and (2) scleral contact lenses, which in addition to covering the cornea, extend out onto the sclera for some millimeters. Corneal lenses are more comfortable to wear, more rapidly tolerated and in general can be worn for a longer period. They are, however, more readily lost from the eye either by quick movement or sudden jolt of the head. They cannot be used by swimmers, since they would immediately wash off when the eyelids are open. Scleral contact lenses, on the other hand, are in general less comfortable, can usually be worn for lesser periods but do have the advantage that they are not easily dislodged since the eyelids press them into position. These can be worn

by swimmers. Recent technical modifications have improved their wearability.

For those who cannot tolerate contact lenses and yet need glasses for visual purposes, several types of eyeglass frames have been devised. These can be obtained from any competent optician.

INJURIES

When an injury to or about the eye occurs, the question immediately arises as to its degree of seriousness and whether ophthalmological advice should be secured. The dividing line between trauma which is essentially innocuous and that which is potentially dangerous to eyesight, may be fine and at times may be impossible to establish. If one is able to estimate the degree of force applied, one may hazard a guess that no serious sequelae will eventuate. That such estimate may be unreliable is exemplified by the history of a recent patient, who while sitting quietly at a restaurant table was struck in the orbital region by a waiter carrying a tray of dishes. Only a minor external contusion was noted immediately, yet diplopia shortly appeared and roentgenograms of the orbit demonstrated a displaced fragment of the medial orbital wall. This had not been promptly noted because the paucity of presenting symptoms did not make roentgenological study mandatory.

In many instances a competitor in the excitement of a game, may underestimate the severity of a blow and pay little attention to it. It is not at all uncommon for ophthalmologists to see individuals who have been hit in the eye with some such object as a squash or a tennis ball. The immediate history is one of temporary blurring of vision and recovery, only to be followed some weeks later by marked loss of vision. Examination thereupon reveals detachment of the retina. If a competent funduscopic examination with the pupil fully dilated had been made immediately after the incident, it is likely that hemorrhage and edema would have been seen in the peripheral retina, and in all probability a small tear would have been observed. With present methods of observation and treatment such small tears can be readily treated with very little discomfort to the patient.

Certainly any injury in which there is subjective disturbance of vision, such as alteration in visual acuity, loss of visual field, or diplopia, calls for an immediate ophthalmological survey. In addition, similar advice should be sought in the presence of obviously abnormal conditions, such as displacement of the pupil or eyeball, hemorrhage into the anterior chamber of the eye, and excessive edema and chemosis other than the usual "black eye."

CONTUSION

Contusion represents one of the most common types of injury and is ordinarily manifested by the well known black eye. It is due to the rupture of small blood vessels in subcutaneous tissues of the lids. As with hemorrhage elsewhere in the body, it is usually self-limiting. Since the skin of the eyelids is the thinnest in the body, and the subcutaneous supporting structures are equally tenuous, hemorrhage in this area is manifested by more rapid and extensive swelling than is encountered with contusions in other parts of the body.

The pertinent effect upon the athlete is that local swelling mechanically closes the eyelids so that it is impossible for him to see. In the past, professional trainers have been known to incise the skin of the swollen lid with a razor blade in order to evacuate blood and lessen the mechanical swelling. This unwholesome practice is no longer countenanced but even if it were performed by a surgeon under aseptic conditions, it would probably have little practical value. Blood is diffusely spread through the tissues and not loculated so that it can be easily evacuated. The usual first aid measures of iced packs, application of beefsteak and similar procedures, have little value other than psychotherapeutically. Once blood has extravasated into tissues from a ruptured blood vessel, external applications will be of little help in hastening its absorption. We have not been enthusiastic about the use of systemic enzymes, such as trypsin, following a recent experience in which a large but well localized periorbital hemorrhage promptly extravasated into the face, neck and chest, after the administration of the enzyme. Because of extensive vascular supply to the lids, healing is prompt and absorption of fluid and blood products occurs within a few days. Rarely does a localized hematoma become infected or require surgical evacuation.

Contusion alone can cause dislocation of the lens, hyphema, retinal edema, retinal hemorrhage, vitreous hemorrhage, retinal tears and retinal detachment. It may also rupture the globe subconjunctivally. Such severe injuries,

however, are almost invariably accompanied by intraocular hemorrhage and loss of vision which is obvious to the patient. All such injuries require specialized skill for both diagnosis and treatment, and this should be immediately obtained.

ORBITAL FRACTURES

It has been noted herein that due to the arrangement of bones of varying density, as well as the curves, buttresses and tiebars exemplified by the zygomatic arch and orbital rim, considerable resistance to injury is present. Force from a blow to the area is transmitted in a variety of directions so that no concentration is directed at the eyeball. Not uncommonly a depressed fracture of the orbital floor may occur without injury to the orbital rim. The clinical result is traumatic retro- and inferoplacement of the globe producing the entity of traumatic enophthalmos. During the first week or so the presence of this condition may be masked by edema and hemorrhage in the orbit. It may be first suspected when edema has subsided sufficiently so that the patient can open his eyelids and note the presence of diplopia. The importance of its recognition lies in the fact that treatment, if accomplished within the first week to ten days, is a relatively easy matter, but that after this period enough fibrosis and repair have occurred so that reduction of the fracture is a considerably more complicated procedure. Diagnosis depends upon exacting roentgenographic technic. In fact, the condition although known was largely unrecognized until Pfeiffer [4] emphasized not only its frequency, but particularly the necessity of correct radiological technic. The importance of proper centering and positioning of the head to obtain a symmetrical projection and the value of stereoscopic examination were noted by him. Single films often give a picture which is difficult to distinguish from sinusitis, but stereoscopic projections in the Caldwell and Waters position readily demonstrate depression of the orbital floor into the antrum which even an inexperienced observer can see. At one time or another the condition of traumatic enophthalmos has been attributed to: (1) injury to Mueller's orbital muscle, (2) injury to the check ligaments, (3) rupture of Tenon's capsule, (4) atrophy of orbital tissue due to injury of sympathetic and trigeminal nerves, (5) hemorrhages of the ophthalmic artery behind the ciliary body, (6) hemorrhages into nerve sheaths, (7) cicatricial contraction of orbital tissue following inflammation, (8) cicatricial adhesions to the eyeball, (9) cicatricial contraction of the extraocular muscles, (10) absorption of orbital fat due to the pressure incident upon severe cellulitis, (11) similar pressure atrophy following an orbital hematoma, and (12) gross destruction of orbital content. As Pfeiffer has pointed out, adequate roentgenographic technic will demonstrate a depressed fracture of the orbital floor in almost every case.

A not uncommon orbital fracture is that in which the force of the blow is transmitted through the eyeball to the medial wall of the orbit resulting in a fracture of the lamina papyracea of the ethmoid. The patient most frequently becomes aware of this when, upon blowing his nose, the eyelids and at times the conjunctiva suddenly balloon up and close the eye. Upon gentle palpation of the lids, the examining physician can readily feel crepitation in the tissues. When the patient is advised to discontinue blowing his nose, the condition ordinarily subsides promptly.

In general, treatment of orbital fractures is beyond the scope of the usual team physician, but his alertness to its possible presence, and prompt diagnosis with adequate roentgenographic facilities, may save the patient considerable future distress.

A rather rare, but thoroughly frightening experience both to the patient and to the physician who has never encountered the condition, is the complete anterior luxation of the globe between the eyelids. When this occurs the lids clamp down behind the proptosed globe. Retroposition is a difficult matter, which is not aided by the apprehension of the patient. Reduction should be performed promptly and in the following manner: With the patient lying in a recumbent position, instillation of a local anesthetic such as tetracaine 0.5 per cent on the eyeball and gentle retraction of the lids with muscle hooks or small retractors, will permit the physician to return the globe to its proper position, usually none the worse for its experience.

LACERATIONS OF THE EYELIDS

Lacerations of the skin alone, such as horizontal tears which occur in the eyelid and eyebrow in boxing, can be repaired by any

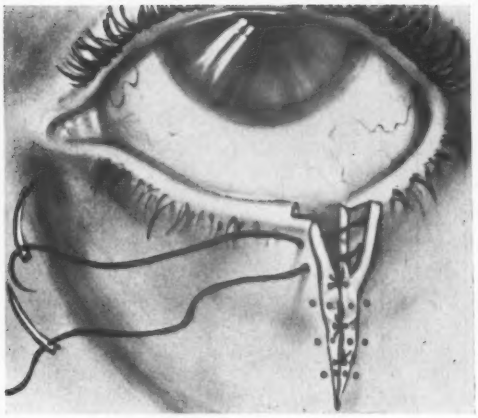

FIG. 1. Repair of laceration of lid. Halving principle.

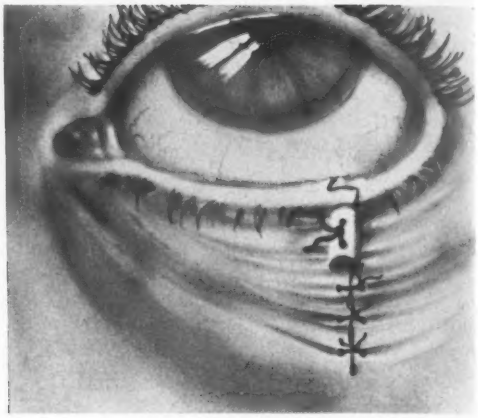

FIG. 2. Repair of laceration of lid. Closure.

surgeon. The use of No. 6–0 black silk sutures closely spaced is recommended, but healing in this area occurs quite readily and even rather roughly approximated wound edges in lids heal usually without perceptible scar.

Those lacerations, either contused or incised, which split the lid vertically and which go through its thickness, are an entirely different matter. Their repair calls for specialized technic and, unless performed by one who is trained in this field, will eventuate in deformation of the lid and a disfiguring scar. The frequent partial avulsion of the lower lid which occurs at the inner canthus of the eye and is associated with a transection of the lacrimal canaliculus belongs in this group.

Although it is true that injuries of this type should be repaired as promptly as possible, nevertheless, if competent help is not immediately at hand it is better judgment to temporize until such technical skill is available. Should it be considered necessary to repair a vertical through and through laceration the following technical points are important: First, it should be remembered that anatomically the lid can be divided into two halves, the first or anterior half containing the skin and the orbicularis muscle, the posterior half being made up of the tarsus and conjunctiva. The essential point in repairing injuries in this area is that the incisional closure line of the anterior half should not be directly over the incisional line of the posterior half. In other words, a half lap or halving joint of the carpenter should be the aim. To accomplish this it is necessary to split the lid into its two component halves for a distance of 1 to 2 mm. on either side of the incisional line. (Figs. 1 and 2.) A millimeter or two of the tarsal-conjunctival half is removed from one side and a corresponding amount removed from the skin muscle layer of the opposite edge of the wound. Sutures (usually double armed No. 4–0 black silk sutures on Atraumatic® needles) are then placed so that snug approximation of the wound is produced. Superficial closure of the skin is accomplished with No. 6–0 black silk. If the halving type of closure or some modification is not used, a disfiguring notch in the lid is virtually certain to occur in any injury which is through the full thickness of the upper or lower eyelid.

Repair of a severed lacrimal canaliculus is a difficult procedure at best, and one not likely to be successfully accomplished by an untrained operator.

In most instances, treatment of severe lacerations of the lid will be limited to first aid measures by the team physician. Should the eyelid be partially avulsed exposing the cornea, it should be laid back gently into position over the cornea and a light dressing applied. If definite repair cannot be accomplished immediately, the use of a broad spectrum antibiotic is desirable. The usual antitetanus measures are in order. In this situation, the principal aim is to be sure that the cornea is properly protected, since without adequate lid covering serious dehydration of the cornea may occur rather rapidly. Usually, sufficient lid tissue remains so that it can be used to cover the cornea, if necessary, a rough temporary approximation being accomplished with a No. 4–0 black silk suture. In the rather unusual situation in which there has been total avulsion of an upper eyelid

without injury to the eyeball, it is possible to secure temporary protection by forming a cone of cotton or gauze, filling it with some bland ointment and inverting it directly on top of the cornea where it can be held in position with adhesive straps. Total avulsion of the lower lid is not a serious problem from the standpoint of preservation of function of the eyeball.

FOREIGN BODIES AND PERFORATING WOUNDS OF THE EYEBALL

Perhaps the most commonly encountered ocular injury is the minor but annoying disturbance caused by the retention of a small foreign body beneath the upper lid. It should be remembered that these usually lodge in a narrow sulcus near the lid margin and can be removed by everting the upper lid. This latter maneuver can be embarrassingly difficult at times but if the examiner will remember to have the patient look extremely downward and will pull the lid outward before folding it upward, the procedure will be greatly faciliated. It should also be noted that many foreign bodies give the sensation of being in the upper lid when they are embedded in the cornea. Their presence is frequently missed because the examination is improperly performed. Oblique illumination from a small concentrated light source, such as a pencil flashlight, will immediately reveal the foreign body. Removal can usually be effected with a cotton tipped applicator or by irrigation from a syringe. Embedded foreign bodies which do not wipe off readily should be handled by a specialist.

Any injury in which there is actual or suspected perforation of the eyeball with or without a retained foreign body, is an extremely serious situation demanding immediate attention. No such injury can be treated by one not specifically trained. If a foreign body is thought to have entered an eye, as might occur in rifle shooting in the presence of a defective breech mechanism, it may be helpful to save a piece of the original material from which the foreign body is thought to have fragmented. It may, for example, be helpful to determine the degree of magnetism of the material in order to estimate the chances of its removal. Pending the arrival of an ophthalmic surgeon, a preliminary scout x-ray film of the orbital region may be helpful in order to establish the presence or absence of foreign material. Precise localization of an intraocular foreign body requires specialized equipment.

It need hardly be emphasized that any perforating injury demands immediate attention. Most physicians are aware of the peculiar entity, sympathetic ophthalmia, which seems to have no counterpart in other organs of the body. In this disease a severe inflammatory process develops in the injured eye, which after a varying period of time may be reproduced in the uninjured eye. Quite frequently the disease in the sympathizing or uninjured eye may be far more severe than in the originally injured eye. Until the advent of steroid drugs, treatment was notoriously unsatisfactory. Even now treatment of the condition can be a harrowing one to the physician and patient alike, so that prevention rather than cure should be the aim.

It is well known that removal of the injured eye, prior to the onset of inflammation in the sympathizing eye, will prevent its occurrence. Etiology is not definitely established but is presumed to be due to the development of autosensitivity to some ocular tissue, probably uveal pigment. Development of sympathetic ophthalmia rarely, if ever, occurs before the tenth day following an injury and seems to be most apt to occur at about the thirty-day period. There are many cases on record in which the disease did not develop for months or even years following an injury. It is apparent, therefore, that treatment calls for a considerable amount of clinical judgment.

In general, unless an eye is obviously injured beyond all repair, the course usually followed is immediate repair of the injured eyeball followed by close observation for a period of ten days or so. If at the end of this time the patient has reasonably good vision, and the inflammatory process seems to be subsiding, it is generally considered good judgment to assume the calculated risk which follows any perforating injury and continue observation and treatment. If, on the other hand, at the end of the ten-day period, the eye is blind, soft, and shows evidence of increased inflammatory response, further delay should not be permitted but the eye should be removed immediately.

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Facial Injuries in Sports

$F = MV^2$

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THE diversity of sport activities, from archery to zooming about on a sports car track, can account for any conceivable mechanism or type of facial injury. Most athletic injuries to the face result, however, from bodily contact, the intentional force of the boxers fist or the accidental force of the head, knee or shoulder against the face, from collision of the face against the ground or projecting stationary objects, or from the missle effect of a traveling ball, bat or hockey stick. The force is more often a factor of mass than high speed velocity and the result is contusive, lacerative and fracturing rather than piercing. Facial injuries are high in incidence, e.g., over 50 per cent of all injuries in high school football.

PREVENTION OF FACIAL INJURY

In amateur athletic activities prevention falls into the categories of supervised training and play, elimination of dangerous obstacles in playing areas, and protective padding or guards, i.e., helmet, face bars, and rubber dental mouth pieces.

EMERGENCY TREATMENT

Initially, one is concerned with preservation of the airway and control of bleeding. The tongue can be brought forward by thrusting a safety pin through the tip of the midline, and a string to the pin. This will maintain an airway that might be collapsed by injury to the jaw portions. The patient should be transported lying upon his abdomen, the face down and to the side. The airway is thereby preserved and aspiration of blood and mucus is prevented; tracheotomy is seldom necessary, but should be performed if needed, such as with concomittant laryngeal and neck contusion.

Bleeding can usually be controlled by a pressure dressing over the skeletal parts. Occasionally, packing may be necessary. Only rarely is the application of a hemostat necessary. So-called "pressure point" control and vessel ligation are rarely indicated. Occasionally, a hemostat applied to a visible open bleeder in a deep wound may be required.

DEFINITIVE TREATMENT

Assessment of the patient's general condition and concomitant injuries will establish any priority of treatment to be given; concomitant treatment and diagnosis of the facial injuries including accompanying fractures are necessary.

Before proceeding beyond the control of hemorrhage and the maintenance of an airway in the patient with a facial injury, shock, injury to the long bones and abdominal injury are assessed and treated. A concomitant injury to the head affecting consciousness or responsiveness is not a contraindication to proceeding with facial injury, although the patient's response with regard to blood pressure, respiration, etc., should be satisfactorily stabilized before proceeding with facial repair. Drainage of cerebrospinal fluid due to dural tear and leakage through the nose is not a contraindication to repair of facial fractures, especially fractures of the nose. It was formerly so thought, but indeed, repositioning of the broken facial parts will hasten the opportunity for dural healing and cessation of the drainage of spinal fluid. Antibiotic protection against meningitis allows one to so proceed. A cervical fracture may contraindicate movement, turning of the head and manipulations otherwise necessary for the taking of certain roentgenograms and the treatment of the facial injury.

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DIAGNOSIS OF FACIAL INJURIES

The existence of a laceration and much of its extent are self-evident. Coexisting damage to the facial nerves, division of the parotid duct and concomitant damage to the eye globe must be considered. The former two are considered later in this discussion. Coexisting fractures of the facial bones along with lacerations are diagnosed by asymmetry of appearance, palpation for disturbance of normal bony landmarks and determination of crepitus, testing of occlusion of jaw and appropriate roentgenograms. The most frequent facial fractures in order of frequency are those of the nose, lower and upper maxillas and the malar bone.

TECHNICS OF TREATMENT APPLICABLE TO MOST FACIAL INJURIES

In general, a fracture should be repositioned early, and concomitantly or before the repair of lacerations in order to give proper supporting structure. This is highly preferable to the more common practice of sewing up a laceration and allowing a fracture of a facial bone to proceed to fibrosis or malunion in a displaced position. Locally administered anesthesia is often sufficient for reduction of fractures, especially when seen early. Infiltration anesthesia is satisfactory and in some regions, a fifth nerve block is indicated, e.g., reduction of mandibular fractures. Antibiotics, erythromycin being typical, are given. Inoculation with tetanus antitoxin or tetanus toxoid is carried out. Gas bacillus antitoxin is not given as it is not indicated. Gas bacillus gangrene of the facial wound is practically never encountered and is prevented by surgical cleansing and revision of the wound. All viable tissue, even of apparently questionable circulation, is preserved including soft tissue and bone with periosteal attachment. Skin grafts are used when avulsion is great enough so that attempted suture would result in undue tension.

TECHNICS OF SPECIFIC TREATMENT

Injury to the Nose. Fracture of the nose is identified by visual displacement and crepitus on palpation. Roentgenograms may be confirmatory or in some cases may not reveal fracture. They should be taken nonetheless. Reduction is usually well accomplished. The nose is anesthetized by the insertion of sterile cotton immersed in equal parts of 10 per cent cocaine and Adrenalin® intranasally. This anesthesia is supplemented with 1 per cent Novocain® infiltration. The parts are manipulated into position by an internal blunt instrument such as a probe or hemostat and external simultaneous manipulation with the fingers. After reduction, the fragments will remain in place unless the fractures are comminuted and involve the septum as well as the side walls. In the latter condition, internal nasal packing is necessary. A padded external metal splint retains the parts in proper position. Severe comminution requires elevated support by through-and-through nasal wires tied over lead plates on the sides of the nose. Concomitant lacerations are repaired. Any hematoma visualized within the nose is incised and aspirated to prevent destruction of cartilage and necrosis.

Mandibular Fractures. Mandibular fractures are identified occasionally by distortion in appearance, palpation and especially by testing dental occlusion. If the occlusion is irregular indicating fracture along the horizontal ramus or of the ascending ramus with dislocation of condylar relationship, the bite will be improper and uneven from one side to the other. Local tenderness over the site of fracture is common. Palpable displacement is often diagnostic. X-ray films are very important for the quantitative aspect of displacement of fractures. When the mandible alone is involved, reduction is accomplished in over 90 per cent of the cases by simple interdental wiring. Arch bars wired to the teeth and interconnected with wire fixation are the alternative. When insufficient teeth are present, fixation by means of Kirschner wire or open reduction and interosseous wiring is necessary.

Maxillary Fractures. These fractures are diagnosed by abnormality of position, abnormal motion, and roentgenograms. The fragments are repositioned and secured by interdental wiring. They may need auxiliary support through direct facial wiring in the region of the orbit, or wires led from a paraorbital drill hole down to a metal arch bar wired to the teeth.

Injuries to Teeth. Although it is not my purpose in this paper to discuss prevention of facial accidents to any extent, it is warranted to stress the value of an individually constructed latex mold for the upper alveolus and teeth. Such a protection is comfortable, permits easy breathing and talking, and is of immense help in lowering the high incidence of injury to the

teeth in contact sports. It is inexpensive and not difficult for a dentist or dental technician to fashion.

Fractures and chipping of teeth may lead to devitalization and loss. Expert dental attention is most urgent. Temporary protection of chipped areas may be given by application of Ward's surgical cement or thin acrylic shells. Early dental treatment is necessary to preserve vitality or prevent infection of the root.

Loosened teeth need not be removed. Indeed, they should be gently aligned and held with segments of arch bars or dental bands. Often the peridontal membrane will heal and the teeth again become solidly fixed. Preparation of the canal or apicoectomy, etc. may be necessary but the teeth can be preserved and bridge work replacement be postponed or prevented.

Malar Fractures. Fractures in this area frequently involve the orbit. Deformity is seen early but within a few hours is obscured by swelling. Palpation may reveal abnormalities of the infraorbital rim. Diplopia, as an abnormality of extraocular muscle damage or displacement should be noted. Concomitantly, vision and eyeball tension should also be tested, for edema may develop retrobulbarly and require incision of the tensor fascia to prevent blindness. X-ray films of the malar bone and infraorbital rim, particularly in the Water's position, and special views for the zygomatic arch are indicated. Early repositioning can be carried out rather simply by the introduction of a sharp hook such as a towel clamp. After a few hours in the presence of swelling, such reduction is no longer possible and open reduction is required. Fractures of the orbital rim are often best treated by open reduction through overlying incisions and interosseous fixation by No. 26 stainless steel wire passed through drill holes placed on either side of the fracture site.

Closure of Lacerations. Lacerations are cleansed by the washing of adjacent skin with cotton pads and bland soap or other detergent and copious flushing of the wound with saline solution. Ragged skin edges are minimally pared at right angles to the surface through the layers of skin. Obliquity of the wound is followed beneath the skin layer for any débridement of contused soft tissues. Débridement is indeed minimal. All facial tissue which has a semblance of vitality and circulation is saved. Closure is in layers with No. 4-0 or 5-0 catgut or silk sutures in muscle and subcutaneous tissue, and for the skin, No. 5-0 dermalon. Skin sutures are placed 2 to 3 mm. apart and tied quite loosely. Stitch marks are avoided by the use of a compression dressing and removal of skin sutures in forty-eight to seventy-two hours.

In the closure of a laceration, known fixed points are used for approximation, e.g., vermilion borders of the mouth, the grey line of the eyelid, eyebrow, etc. After these orientation sutures are placed, the remaining segments are closed and distortion thus avoided.

Avulsion areas of full thickness of skin are covered by thin split grafts taken elsewhere. Although the best color match is obtained with a full thickness skin graft taken from behind the ear, the upper eyelid or the supraclavicular area, such repair is frequently a later procedure rather than an immediate one.

Attempts to close large avulsed areas by direct suturing result only in additional suture scarring, tension, loss of circulation and slough. The closure of an ordinary wound with a few large through-and-through sutures promotes hematoma, additional scarring and deformity.

When a laceration is posterior to the anterior border of the masseter muscle, consideration of damage to the facial nerve and parotid duct must be considered. The facial nerve is tested as to motions of the face and if lacking, the wound should not be sutured until visualization and repair of the facial nerve branches have been performed. If the wound is so contused as to contraindicate this, temporary closure may be indicated with a view to later repair.

Lacerations in Special Locations. The location of the laceration creates suspicion of damage to the parotid duct when the wound is deep. Confirmation of this injury is obtained by passing a ureteral catheter or fine polyethylene tube from within the mouth into the opening of Stenson's duct. The catheter will emerge into the wound if the duct is divided therein. The proximal end can then be found by adjacent location and the catheter or tube passed into the proximal portion. Closure of the duct is then carried out with interrupted sutures around the catheter used as a splint. A wire is alternative to the tube and can be maintained in place in the cheek until healing of the duct is complete.

Lacerations of the eyelid require particular

djustment to avoid notching deformity. Lacerations of the inner canthus of the eye may involve the lacrimal duct and again the probe method or a blunted needle and dermalon is used to pass through and re-establish continuity of the lacrimal duct.

Contusions of the Ear. When the auricle is severely contused against the firm temporal area, blood and serum collect on both sides of the cartilage. This isolates the cartilage from the soft tissue upon which its nourishment and vitality depend. Chondritis of the necrosis type ensues, the structural support collapses, and a "cauliflower" ear results. The treatment of contusions of the ear, then, is the aspiration of hematoma from both sides of the cartilage and the prevention of the reformation of fluid. This is accomplished, following aspiration, by the application of a "stent" of mineral-oil-moistened cotton carefully fitted into all the convolutions of the anterior auricular folds and also placed postauricularly. Upon the stent is placed fluffed gauze held in position with adhesive tape to prevent shifting. The outermost layer of the dressing is then applied, a circular head bandage of moderate elasticity, such as that afforded by a Kling® bandage. The dressing must be maintained for ten days, or else reaccumulation of serum will recur in the unsupported damaged area. Chronic chondritis will require removal of necrotic cartilage and otoplasty, with only limited improvement to be expected.

IMMEDIATE AFTER-CARE

The need for antibiotics has been mentioned. Feeding is carried out by the use of a nasal tube in patients with extensive facial injuries or by a liquid or gruel diet taken with a suction straw. It is not necessary to remove a tooth in order to feed a patient.

Strict attention to oral cleanliness is necessary to afford better wound healing of involved intraoral structures, such as cheeks, tongue, gums and tooth sockets. The frequent use of an alkaline mouth wash will keep the mouth clean, comfortable and free of odor.

SUMMARY

Facial injuries should be diagnosed with regard to fractures as well as lacerations. Appearance, examination, palpation, testing of occlusion and roentgenograms are needed. Fractures are best reduced early, along with closure of lacerations. Lacerations should be cleanly prepared with minimal débridement saving all tissue, and closed in layers to avoid scarring, distortion and abnormality of function.

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The Mechanics of Some Common Injuries to the Shoulder in Sports

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IT is the purpose of this paper to discuss the mechanics of injuries about the shoulder related to athletic trauma. Such injuries differ from those found in ordinary pursuits in that they occur, not in the normal working ranges of motion and usage, but at the extremes of motion and under conditions of severe muscular and ligamentous stress. Each sport presents its own peculiar problems related to the training and conditioning required, the conditions of play, the necessity for knowledge of game skills, the protective equipment used, and the supprvision employed. This is in turn modified by the age and maturity of the participants. The growing bones, joints, ligaments, and muscles of pre-teen and teen-age competitors are subjected to unusual strain, while the more mature, game-wise college or professional athlete places fully developed tissues under stress. The aging or occasional athlete who tends to concentrate more on individual rather than team sports may present an entirely different picture. To assume that all trauma related to the field of sports could be covered here would be presumptuous; rather it is the objective of this paper to discuss some of the standard situations which have been found to be the basis of a constantly recurring pattern of trauma in the hope that a better understanding of these situations will lead to prompt recognition and diagnosis of the more common injuries, which by nature are primarily of the musculoligamentous type.

Those who first come in contact with athletics are often bewildered by the terminology used by the coach, trainer, or player to describe an injury. This terminology—some specific, some general, some descriptive, and some tinted with mysticism—has become so ingrained that there is little hope for its immediate abandonment in favor of the more precise anatomical and pathological evaluation. Since it is of definite value in understanding the general type of injury present, interpretation and translation of these terms into specific traumatic entities is desirable. Our glossary must include the following: (1) The point of the shoulder—The outer edge of the acromion process of the scapula; (2) Shoulder pointer—Contusion of the acromion and adjacent deltoid muscle; (3) Inside shoulder strain—Strain, minor tear, or contusion of the rotator cuff (supraspinatus, infraspinatus, and teres minor); (4) Shoulder separation—Sprain, subluxation or dislocation of the acromioclavicular joint; (5) Shoulder dislocation—Subluxation or dislocation of the shoulder (glenohumeral joint); (6) Shoulder nerve injury—A syndrome characterized by pain and swelling of the deltoid, weakness and numbness of the forearm and hand of five to ten minutes' duration followed by weakness of abduction of the shoulder of about two weeks' duration; (7) Knocked down shoulder—A unilateral lowered position of the shoulder. When acute, this is usually the result of trauma to the shoulder-neck interval; when chronic it is related to habitual malposture; (8) Muscle strain—Strain or tear of body of the muscle; (9) Pulled muscle—Strain or tears of muscle near its tendinous insertion; (10) Pulled tendon—Tears of the tendon at its bony insertion; (11) Glass arm—A chronic musculotendinous strain or tear of the stabilizers and prime movers of the shoulder (glenohumeral) joint associated with the throwing sports (i.e. baseball, etc.), and characterized by pain and

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disability after a short period of use; and (12) Collar bone—Clavicle.

The function of the shoulder is to provide a firmly anchored yet mobile base from which the arm and hand can operate in the many positions required in their use. Possessing little inherent mechanical stability, it depends upon powerful musculature and ligamentous strength for its integrity. The synchronous interplay of the four joints which form the shoulder complex provides the ultimate mobility required of the athlete. Of these, the shoulder (glenohumeral) and acromioclavicular joints are particularly susceptible to trauma due to blows, falls and overuse. The relation of posture to injury must not be overlooked. Since a well aligned machine will work more efficiently and last longer than one which is poorly aligned, it may be anticipated that in the presence of postural malalignment abnormal wear and biomechanical breakdown may result. Such malalignment may be caused by poor general posture, alteration of general posture due to injury away from the shoulder (i.e., an injured foot), to changes within the bony structure of the shoulder, or due to injury or overload of its strong supporting musculature. This predisposing factor may lead either to an acute injury or to repeated minimal injuries whose cumulative effect result in chronic affectations.

Throwing is an extremely complex motion which embodies four essential steps for its proper execution: the initial stance, the wind-up preparatory phase, the initial forward action of the arm prior to release, and follow-through. Although the action of the arm is the most obvious one, leg action, pivot and trunk movements are equally esse..tial to properly executed forceful delivery. The shoulder acts like the handle of a whip, lashing the forearm and hand forward in the throwing motion. The scapula provides a firm base for the arm. It is held snugly to the chest by the trapezius and serratus. As the arm is drawn backward into a position of abduction and external rotation by the posterior deltoid, latissimus dorsi, and infraspinatus, the pectoralis major and anterior deltoid are placed on a stretch in a position of readiness for powerful contraction while at the same time the scapula is drawn backwards on the thorax by the posterior scapular muscles. The body now initiates forward motion of the arm as it moves ahead, pivots and rotates about the spine. This is followed by the synchronous movement of the scapula and humerus. The latter is now whipped into strong internal rotation and flails the forearm and hand into the follow-through position. Throwing varies greatly in different sports (baseball, football, javelin, discus, etc.), and within the same sport (fast ball and curve pitching, outfielders and catchers' throwing, etc.) due to the requirements of the game, style, physical status and the weight and distance the object must be thrown.

The application of physiologic principles will act as a guide to the mechanics of injury. Injuries to the tendon insertions and elastic elements of muscle will occur at the height of the length-tension curves of muscle. Here the muscle is stretched to a point at or near its greatest length. Resistance is largely furnished by the elastic elements of muscle of the intra- and extracellular type while the contractile element plays little part. If the muscle is overloaded at this point, further elongation will result in tears within the elastic tissues of the muscle itself, at the musculotendinous juncture or tendon insertion, or, if the tendon is degenerated, within the substance of the tendon itself. Injury to the contractile elements of muscle occur at or near the mid-point of the contractile curve which corresponds with the so-called rest length of the muscle. (This is the point to which an isolated muscle will contract when released at its extended length without stimulation of its innervation; this contraction is due to the elastic elements within the muscles.) Since muscle tension is dependent almost entirely on contractile elements, they will bear the brunt of the strain and overloading will cause injury primarily involving the muscle fibers. (Fig. 1.)

Injury to the ligaments and joints occur when the muscles stabilizing the joints are overpowered or muscle balance during reciprocal contraction and relaxation is impaired through weakness, fatigue and incoordination.

Injury to the shoulder seldom occurs in the initial part of the preparatory phase of throwing but as the arm reaches the extremes of backward motion and delivery is initiated by a sudden strong forward motion of the body associated with pivot and forward placement of the left foot (in right-handed throwing) there is a strong tension on the insertions of pectoralis major and anterior deltoid muscles. Here injury may be incurred in one of several ways: (1) repeated check-rein action in the presence

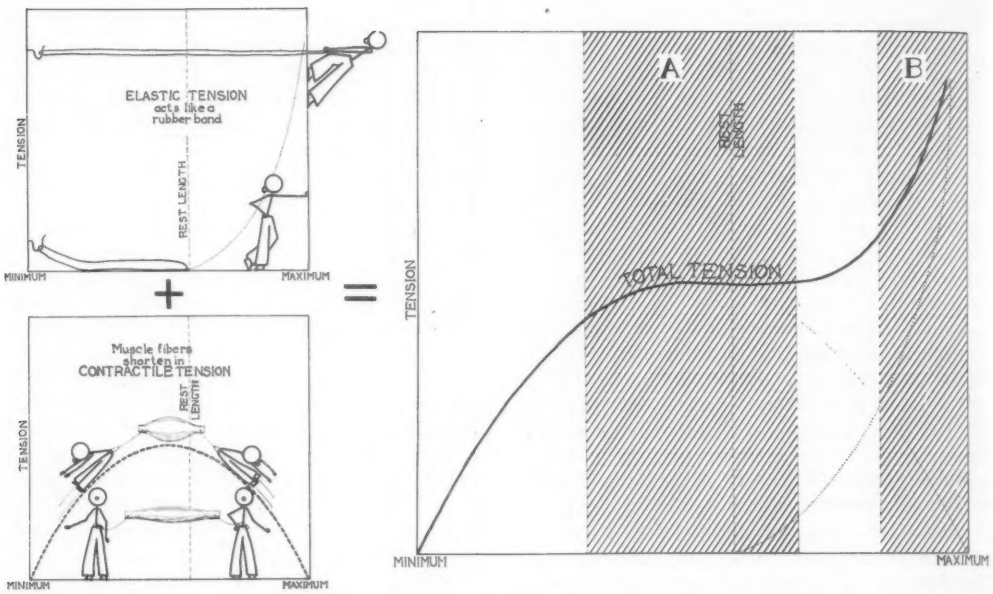

FIG. 1. The total tension curve is the sum of elastic plus contractile tension within the muscle. When the muscle is overloaded to the point of rupture, the contractile elements are most likely to tear if the muscle is in the mid-range of contraction (A) where their contribution to tension is greatest. The elastic elements of muscle are inactive at rest length and exhibit their greatest tension as the muscle is elongated towards maximum length. It is at this point (B) that the tendon may tear away from the bone, separate at the musculotendinous junction, or may actually rupture the elastic elements of the muscle.

of the shortened anterior muscles, (2) the overpowering of the muscle due to excessive force applied when the muscle is already at maximum length, and (3) the tendency for luxation of the biceps tendon from the bicipital groove in the position of abduction and full external rotation (in overhand throwing). (Fig. 2A.)

Injury to the insertion of the pectoralis major on the humerus occurs at the extremes of backward motion. The extended, externally rotated, and abducted humerus places the muscle on a stretch under maximal total tension. This is enhanced if flexibility has been impaired through myostatic contracture of the pectoralis major either on the basis of overdevelopment of the pectoral muscles without attendant development of the posterior scapular muscles or as a result of malposture associated with forward head and shoulders, dorsal round back, and lumbar lordosis and anterior pelvic tilt. Repeated tugging at the insertion of the muscle causes a tender painful area approximately 2 inches in length just posterior to the bicipital groove where it finds its point of bony attachment. This condition is often seen in baseball pitchers and javelin throwers. It is incapacitating for the sport although it may not disturb the arm in ordinary use.

The pectoralis major and anterior deltoid muscles often suffer injury to the tendon and muscle fibers near their insertions during the initial stages of forward movement through overuse in the presence of fatigue or incoordination. At this point the body muscles are near their maximum length and the body moves forward to provide still further tension. Since the contractile power of the muscle is minimal, the full brunt of the load is born by the elastic elements so that an overpowering force will result in tears where this tissue is greatest near the insertion of the muscles. Such a situation may not only arise due to conditions intrinsic to the shoulder, but also due to postural abnormalities caused by remote injuries. It is not uncommon for a baseball pitcher with an injured toe or foot to lose the effectiveness of leg and trunk action. In attempting to com-

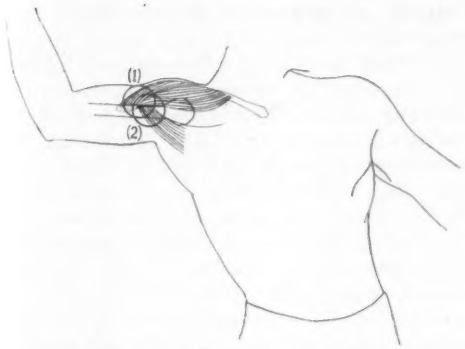

FIG. 2A. The common points of muscle injury in throwing. In the preparatory phase the insertion of the pectoralis major (2) may be irritated by check-rein action when shortened by myostatic contracture, or by added strain upon the strong elastic and tendinous elements near its insertion (2) as forward movement is initiated. The deltoid may also be injured near its anterior insertion on initial forward movement (1).

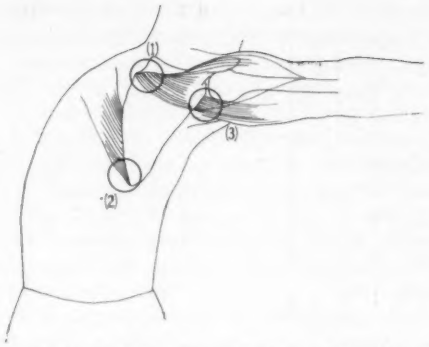

FIG. 2B. In the follow-through phase of throwing, the posterior deltoid (1), rhomboid major (2), or triceps (3) muscles may be injured at or near their insertions due to the limiting effect of elastic tension as the muscle is stretched to maximum length.

pensate for this deficit of force, he may overuse the shoulder in an attempt to compensate for his lost power.

Bicipital tenosynovitis may occasionally occur in early season overhand throwing (or stretching as in tennis) because of the unaccustomed strain on the tendon in the position of full abduction, extension and external rotation where the tendon falls under maximum tension and presses firmly against the lesser tuberosity. Tenderness along the course of the tendon of the long head of the biceps both in its superficial course and beneath the anterior margin of the deltoid and pain on tension and external rotation tests are characteristic. Slipping of the tendon from the intertubercular groove is unusual in the younger group and rupture of the long head of the biceps does not occur from these particular circumstances.

On forward motion of the upper arm while throwing, three areas are commonly injured: (1) the posterior deltoid muscle near its insertion to the spine of the scapula; (2) the scapular insertion of the long head of the triceps immediately beneath the shoulder joint; and (3) the rhomboid major at the lower medial border of the scapula. Each of these occur during follow-through when the muscles come under maximum tension and elongation. (Fig. 2B.)

The injury to the posterior deltoid muscle usually follows overhand throwing. It occurs at the extremes of forward motion when the muscle is fully stretched. It is most likely to occur when proper "warm up" has not been carried out to insure full flexibility and coordination. Injury to the scapular insertion of the long head of the triceps is most commonly a result of curve-ball pitching. Here again the muscle is put on full stretch during follow-through and a further tug is placed on the muscle as the elbow passes into flexion; the typical pain and tenderness in the posterior axillary fold beneath the shoulder results from tears of the muscle near or at the bony insertion of the triceps muscle and is sometimes attended by periosteal new bone formation. Fibers of the rhomboid major at or near the lower medial border of the scapula may be torn during the follow-through phase of throwing. This unusual injury is more common in "underhand" throwing such as is used with the discus.

Injuries to the glenohumeral and acromioclavicular joints and their supporting ligaments result in more disability to the shoulder than is commonly found in other injuries to the soft tissue. Each will be discussed in relation to those types of injury which occur with some frequency.

The shoulder (glenohumeral) joint is frequently injured in athletics following contact with other players or contact with the ground. Since it is well protected by heavy overlying musculature, it is seldom injured by direct contact, but rather by indirect trauma when forces acting on the humerus cause it to act as a lever, prying loose the supporting soft tissues, or when forces are transmitted upward through

the shaft of the humerus contusing or tearing the tissues resisting the thrust of the humeral head. The type of injury resulting depends upon the direction and power of the force applied.

Anterior dislocation is one of the most common serious injuries to the shoulder. The essential episode occurs when the head of the humerus is forced against the weak anterior capsule at any point between the bony pillar of the coracoid above and the tendinous pillar of the long head of the triceps below. The capsule and glenoid labrum are stripped from the anterior lip of the glenoid allowing the humeral head to slip into the subcoracoid region. Subclavicular dislocation with accompanying rupture of the capsule, tearing of the subscapularis muscle, and fracture of the tuberosities is rarely seen in athletic injury although some stretching and contusion of these structures occur.

The reason for the rarity of subclavicular type of anterior dislocation in sports is readily understandable: in non-athletic pursuits its usual cause is a fall on the outstretched hand in which the body weight carries forward and the elbow flexes, throwing the arm into abduction, external rotation and extension so that the neck of the humerus is levered over the overhanging acromion and forced anteriorly out of the joint; in athletic endeavor such a fall is unusual for the trained athlete is agile and is alert to the sudden, dangerous situation.

In contact sports such as football or wrestling the injury usually occurs with the arm abducted near the horizontal so that as the humerus passes backward into abduction and external rotation the pectoralis major insertion becomes the fulcrum of the humeral lever and tends to pry the anterior capsule and labrum from their glenoid attachments. Contracture of the pectoralis major is a predisposing factor. In football, anterior dislocation is usually the result of a tackle in which the tackler looks away from his opponent and passes him too widely while attempting to grasp his thighs; the momentum of the moving player and oncoming opponent forces the abducted upper arm into full extension and levers it from the joint. All degrees of displacement may occur from anterior capsular strain to full anterior dislocation. Inferior and posterior dislocations of the shoulder are of such rare occurence in sports that they do not warrant description here.

Sprain of the posterior shoulder joint capsule and posterior subluxation are frequent in football. They occur in unskilled players who have failed to learn the proper technic of falling in a forward position. The injury is found in ball carriers who fall forward, grasping the ball with the elbow in flexion, and light on the point of the elbow with the humerus in full forward flexion and moderate internal rotation. The force of the fall is transmitted upward through the shaft of the humerus to the posterior capsule of the shoulder joint. Pain and tenderness are found along the posterior margin of the joint and posterior instability is often present.

The rotator cuff may be injured when a player falls with his arm at his side so that force is directed upward through the shaft of the humerus sandwiching the rotator cuff between the humeral head and the overhanging acromion. The cuff may also be damaged by traction injuries. These occur when a rapidly moving player is grasped by the arm and jerked. The strong downward and lateral motion against the tensed cuff muscles may strain or tear the muscular or tendinous fibers. In blocking, an overpowering blow on the abducted arm may again strain the fibers of the cuff. In the right-handed golfer a defect of the rotator cuff on the left shoulder will often cause pain during the follow-through. In this instance the muscles of the cuff fail to snug the humeral head downward into the glenoid while the arm is thrown into full abduction and external rotation.

The clavicle is injured in a fall on the outstretched hand with the arm in abduction and moderate forward flexion. The force of the fall passes upward through the humerus and glenoid, moves the scapula medially, and is thus expended on the clavicle. Similarly the clavicle may be injured by a fall on the point of the shoulder with force being directly inward. Direct injury to the clavicle is rare in sports and therefore fractures injuring the neurovascular bundle are most unusual.

Sprain, subluxation and dislocation of the acromioclavicular joint are simply a matter of degree. The mechanics of injury are essentially the same except for severity of the traumatizing forces. Superior and anterior dislocations are most commonly found while inferior and posterior displacements are rare. The common superior dislocation may be caused either by a fall on the point of the shoulder or a severe blow

to the acromion. In either event the shoulder girdle is forced downward, resisted by the first rib and the upward pull of the sternocleidomastoid and upper trapezius. As this resistance is met the clavicle remains fixed and the shoulder girdle moves downward throwing the strain on the superior acromioclavicular ligaments which, in company with the coracoclavicular ligaments part under stress. Protective equipment, i.e., shoulder pads, materially reduce the incidence of dislocation due to blows from above; thus most injuries result from a fall on the point of the shoulder. Anterior dislocation results when an athlete arising from the prone position is "piled on" from behind. As the trunk is thrust forward, carrying the clavicle with it, it is resisted by the fixed upper extremity. The brunt of the force is born on the anterior acromioclavicular ligaments which part under the stress and allow the clavicle to ride forward. Inferior and posterior dislocations are rare and I have not seen these injuries associated with sports trauma.

The suspensory apparatus of the shoulder consists of the upper trapezius and levator angulae scapulae. These two muscles sweep down from the cervical and upper thoracic spine to attach to the acromion and spine of the scapula and serve to hold the scapula in its normal relationship with the upper thoracic cage. Injury to the suspensory mechanism may result in muscle spasm (the so-called "kink" in the neck), contusion, post-traumatic palsy or unilateral depression of the shoulder girdle. The athletic term "knocked down shoulder" applies to any condition which permits sagging of the shoulder whether it be the result of protective muscle spasm following recent injury or weakness of the suspensory apparatus following repeated minor injuries with or without secondary myostatic contracture. It is a descriptive term and not a diagnosis and as such has no particular value in the study of the injury mechanism or treatment.

The acute kink in the neck is a musculoligamentous injury of the trapezius resulting from sudden stretch of the actively contracted muscle. This usually results in minor tear of the muscle fibers at the angle of the neck. It often follows a sudden twisting movement of the neck when the head is turned to one side while reaching or being pulled by the opposite arm. The latter may occur in football in a pile-up situation as the result of an unexpected arm tackle while cutting in the opposite direction or when a player looks away from an opponent and is struck on the side of the head. In wrestling, a sudden strain may precipitate the condition.

Contusion of the trapezius commonly occurs in inexperienced football linemen who flinch and look away from an opponent and receive a blow from the oncoming knee of an opponent in the shoulder pad-neck interval. Improperly applied shoulder pads (too low) or pads which are too large predispose to this injury. In other contact sports, direct injury may result from the blow of a hockey or lacrosse stick, a kick or blow from the fist.

A sudden severe stretching of the trapezius by an overwhelming force may result in a downward and forward depression of the shoulder girdle. This may cause rupture of the fibers of the trapezius near their clavicular attachment together with a stretch injury or contusion of the brachial plexus. The player experiences a sudden severe pain in the neck, associated with weakness of the arm and tingling, extending downward to the fingers. This most commonly occurs in football from a blow on the top of the shoulder pads usually by the oncoming knee. The sports term applied to this situation is "shoulder nerve injury" although this term is also used for a quadrilateral space injury contusing the axillary nerve and resulting in deltoid weakness in association with posterior shoulder pain and swelling. In the posterior triangle of the neck the accessory nerve, which travels from behind the sternocleidomastoid muscle to enter the main body of the trapezius just over the clavicle (an inch or so), may receive direct trauma resulting in a mild palsy. This injury is rare in contact sports and usually follows direct injury when the player is "flinching" or "loafing."

The unilateral low shoulder ("knocked down shoulder") may result from a variety of causes. Since such factors as scoliosis, poliomyelitis, etc., have been eliminated through the preparticipation physical examination, the principal concern in supervised athletics lies in post-traumatic and postural etiology. Acute trauma to the suspensory apparatus of the shoulder girdle will cause the muscles to go into protective spasm resulting in depression by leaning to the affected side and medial displacement of the scapula. Typically, the patient will come in grasping and supporting the trapezius with his hand in the shoulder neck interval. Repeated

minor traumas to the broad flat posterior muscles of the shoulder complex may also result in protective muscle spasm which draws the scapula downward and rotates the inferior angle of the scapula medially. If such a position is maintained, secondary myostatic contracture may follow fixing the shoulder in this lowered position. Sagging shoulders secondary to malposture are associated with a forward position of the head, dorsal kyphosis and lumbar lordosis. The scapula assumes a forward position accompanied by scapular rotation. The trapezius and levator angulae scapulae become overstretched and weakened. Needless to say, such a shoulder is more prone to injury than a normal one and if injured may assume a position still lower than the other shoulder. Chronic dull aching pain in the suspensory apparatus is typical.

SUMMARY

The mechanics of some common shoulder injuries occurring in sports have been discussed. Such trauma differs from that found in daily practice in that it occurs under conditions of strong muscular effort and at the extremes of motion. The appreciation of the mechanics of injury often furnishes the clue to successful early diagnosis and treatment.

Athletic Injuries to the Shoulder Region

H. F. Moseley, M.A., M.CH.,* *Montreal, Canada*

The shoulder is one of the regions of the body frequently injured in competitive sports. Statistical studies show that 8 [*38*] to 13 per cent [*21*] of the injuries so sustained involve this area.

The particular lesions fall into fairly definite groups, i.e., (1) contusions of the soft and skeletal structures; (2) injuries of the glenohumeral joint, including subluxations and dislocations, fractures and fracture-dislocations of the upper end of the humerus, scapular fractures related to the glenohumeral joint, and various traumatic lesions; (3) injuries of the clavicle and its articulations, including fractures of the clavicle, sprains, subluxations and dislocations of the acromioclavicular joint, and sprains, subluxations and dislocations of the sternoclavicular joint.

The glenohumeral joint is that most frequently dislocated, and in one series 61 per cent of all dislocations were of this joint [*38*]. It should be pointed out, however, that the presence of the recurrent state in some of the athletes accounts in part for this high figure.

Sprains and contusions of the acromioclavicular joint contribute the greatest number of injuries to this area, but the number of complete dislocations with concomitant rupture of the coracoclavicular ligaments is less than that of complete dislocations of the glenohumeral joint. Furthermore, complete dislocations of the sternoclavicular joint are comparatively uncommon. The clavicle is frequently fractured and avulsions of parts of the greater tuberosity and fractures of the acromion are also encountered.

In an article of this type, a certain point of view must be adopted; it is my intention to discuss the subject from the point of view of the surgical specialist to whom the patients are referred by athletic clubs and medical personnel rather than from the point of view of the club physician or the athletic trainer. Thus the disorders to be discussed will be the more serious injuries in which the decision is one of selection of a definitive course of treatment. Furthermore, a difference should be noted between the timing and selection of treatment in the professional athlete who is under contract with a club and the amateur athlete who usually is not influenced by the same economic considerations.

As lesions characteristic of baseball players are discussed by Dr. Bennett, and statistical studies by Dr. Thorndike, these aspects of the subject will be omitted. However, some duplication with Dr. Urist's article will be noted on acromioclavicular lesions.

Contusions of Soft and Skeletal Structures

In body contact or impact sports in which the player is struck by an opposing player or falls heavily to the ground or ice, or against the boards or other immovable object as in hockey, the prominence of the shoulder may sustain contusions of a severity determined by the force applied and the consistency of the surface struck. The resultant injury is again modified by the protective apparel worn.

Contusions of the deltoid and trapezius muscles are the most common lesions, although the skeletal and joint structures more deeply placed are frequently involved to a lesser degree.

The diagnosis is made after a careful analysis of the history, and localization of the site of tenderness and traumatic inflammation. The radiological findings will be negative for fracture or dislocation.

Treatment consists of palliative measures with the application of cold compresses, elastic

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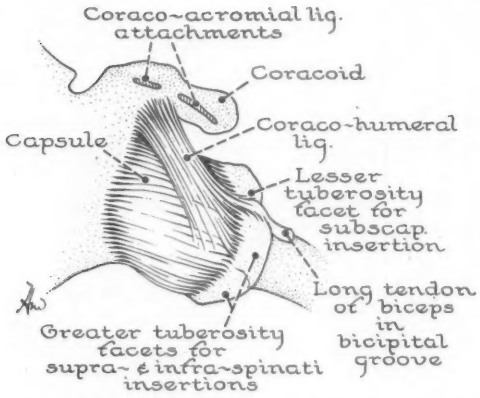

Coraco-acromial lig. attachments
Coracoid
Capsule
Coraco-humeral lig.
Lesser tuberosity facet for subscap. insertion
Long tendon of biceps in bicipital groove
Greater tuberosity facets for supra- & infra-spinati insertions

FIG. 1. Detailed anatomy of the coracohumeral ligament.

pressure bandages and rest for the first twenty-four to forty-eight hours, followed by the use of radiant heat, massage and exercises after this period.

Return to athletic activity will be graduated by the functional recovery.

THE GLENOHUMERAL JOINT

Injuries of the glenohumeral joint have constituted the largest group of athletic injuries referred to me in this center.

The definite lesions include acute subluxations and dislocations of the anterior or posterior types occurring for the first time or as a manifestation of the recurrent state, fractures of the component bones, and a group of lesions which for descriptive purposes may be classified as "traumatic-various."

Subluxations and Dislocations

The glenohumeral joint is the most common articulation to suffer dislocation in sports. Besides, self-reducing subluxations occur more frequently than usually suspected, and I believe that this lesser degree of joint instability accounts for many of the so-called "trick shoulders" and also for the majority of those cases diagnosed as recurrent dislocation of the biceps tendon. In some proved cases, the audible and palpable click has been found to be due to the movement of a mobile labrum over the bony rim of the glenoid. We must also remember that certain joints are inherently lax and unstable, but young men with such derangements usually avoid the field of competitive sports.

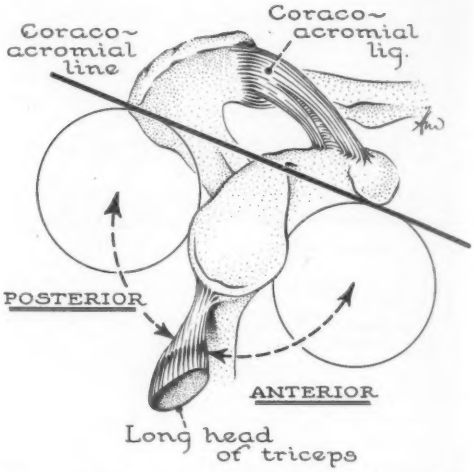


FIG. 2. Sites of exit of the humeral head from the glenoid fossa.

Mechanism of Injury. Anterior dislocation may result from a fall backward on the point of the elbow with the arm in dorsal flexion. The force drives the head directly forward, and Bankart [*1–3*] considered that this was the type of injury which detached the glenoid labrum anteroinferiorly and thus caused the "essential lesion" predisposing to later recurrence. I believe that most dislocations anteriorly are produced by the lateral mechanism when the force is such as to forcibly abduct and externally rotate the humerus. The surgical neck impinges on the acromion as a fulcrum levering the head out of the glenoid fossa anteroinferiorly. The exact site will be determined by the degree of abduction at the moment of displacement, and this is determined by the fixation of the humerus on the scapula by the muscular balance at that moment. If the arm is fully abducted, the subglenoid type will result. If in a position about the horizontal plane of the joint, a directly anterior position will occur. Like many others interested in this field, I do not believe that there is any particular position of dislocation which tends to produce the recurrent state, but that the age of the patient is the determining factor [*22,30,33*]. In the young athlete, the traumatic inflammatory reaction after dislocation is much less than that in the older patient, and all of those interested in this point have confirmed the observations of Hippocrates [*14*] that those dislocations

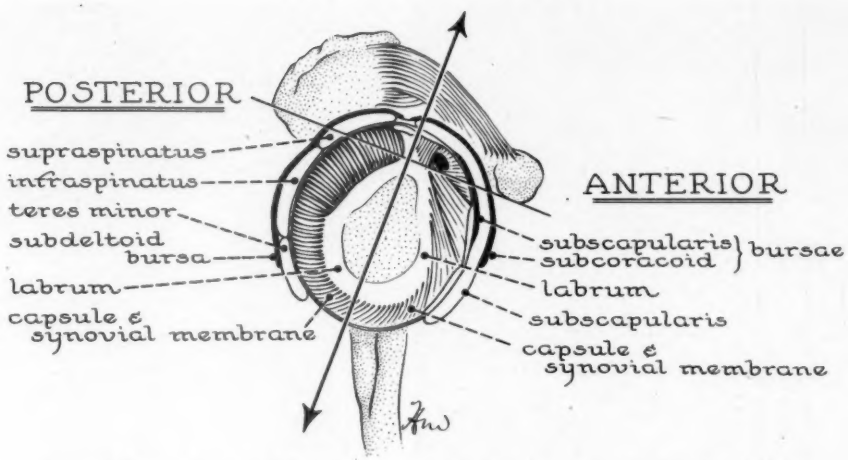


FIG. 3. The anterior and posterior capsular mechanisms in relation to type of dislocations.

which were followed by minimal discomfort and early recovery of function were those which tended to recur.

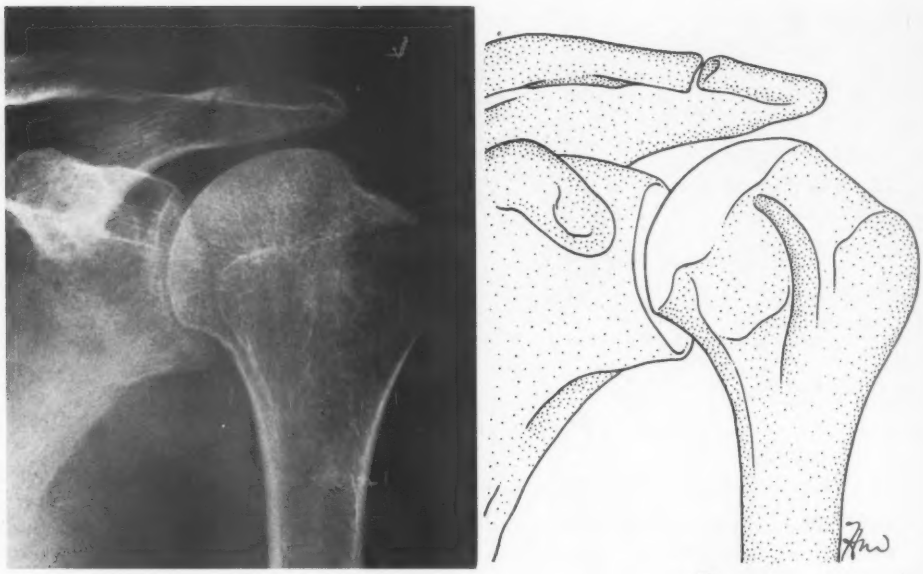
Anterior dislocations can occur after a direct blow on the posterior aspect of the joint and conversely the posterior type can follow a reverse type of mechanism. Posterior dislocation may follow a forced internal rotation of the adducted limb.

Anatomical Considerations. Those acquainted with the original observations of Bigelow [*4*] on the hip, will remember that he was able to produce on the cadaver with the iliofemoral ligament intact and the remaining soft tissues removed, the type dislocations found in clinical practice. On this basis he propounded his method of reduction by circumduction. Few, however, correlate the work of Kocher [*19,20*] and his method for reduction of shoulder dislocations with Bigelow's studies. My impression is that Kocher looked for an anatomical structure in the shoulder corresponding to the iliofemoral ligament and described the cord of capsule which we call the coracohumeral ligament. (Fig. 1.) It is around this tissue that the humeral head will pivot into the various positions of dislocation. Furthermore, as previously described [*24*], the head of the humerus usually leaves the glenoid fossa at a point below a line joining the inferior aspects of the coracoid and posterior margin of the acromion. (Fig. 2.) My studies on the axillary relations of the shoulder [*25*], and operations by the axillary route on patients with recurrent dislocation have demonstrated to me the strong support afforded the inferior capsule by the long tendon of the triceps when the arm is in the position of full abduction at which point most anterior dislocations occur. Therefore the anterior dislocations occur below the coracoacromial line and anterior to the long tendon of the triceps around the pivot of the coracohumeral ligament and a secondary mechanism formed by the long tendon of the biceps. (Fig. 2.)

Further consideration of the soft tissues of the intimate joint structure concerns the capsule with its synovial lining and the musculotendinous tissue of the short rotator muscles. In considering the post-traumatic anatomy of shoulder dislocations, my understanding has been assisted by considering these tissues as forming two components: (1) the anterior soft tissue mechanism consisting of the labrum, anterior capsule, synovial lining, related bursae and the subscapularis, and (2) the posterior soft tissue mechanism consisting of the posterior capsule and labrum from the bicipital groove backward and including the supraspinatus, infraspinatus and teres minor tendons. (Fig. 3.)

General stretching and tearing of these two groups of structures must occur in all dislocations of the joint, and the various lesions found in primary and recurrent dislocations may be summarized as follows:

Lesions of the joint as a whole: (1) General stretching and tearing of the soft tissues of



4A 4B

FIG. 4. A, x-ray film showing the hatchet head produced by repeated subluxation or dislocation, usually in the lax-jointed person. B, diagrammatic representation of the associated x-ray film.

anterior and posterior soft tissue mechanisms. In the recurrent state the extent can often be judged by measuring the joint capacity, which is always greatly increased [24]; (2) in the recurrent state, muscular imbalance and some weakness from favoring the part.

Localized lesions of the anterior soft tissue mechanism: (1) Detachment of the antero-inferior glenoid labrum, with or without fragments of the bony rim; (2) stretching of the glenohumeral ligaments and capsule, forming an anterior pouch; and (3) stretching and laxity of the subscapularis with detachment from the anterior aspect of the scapula.

Localized lesions of the posterior soft tissue mechanism: Stretching of the posterosuperior capsule, the supraspinatus, infraspinatus and teres minor with detachment on the deep aspect. This gives, in cases of recurrent dislocation, the elongated appearance of the humeral neck, the "hatchet head" of the French writers. (Fig. 4.)

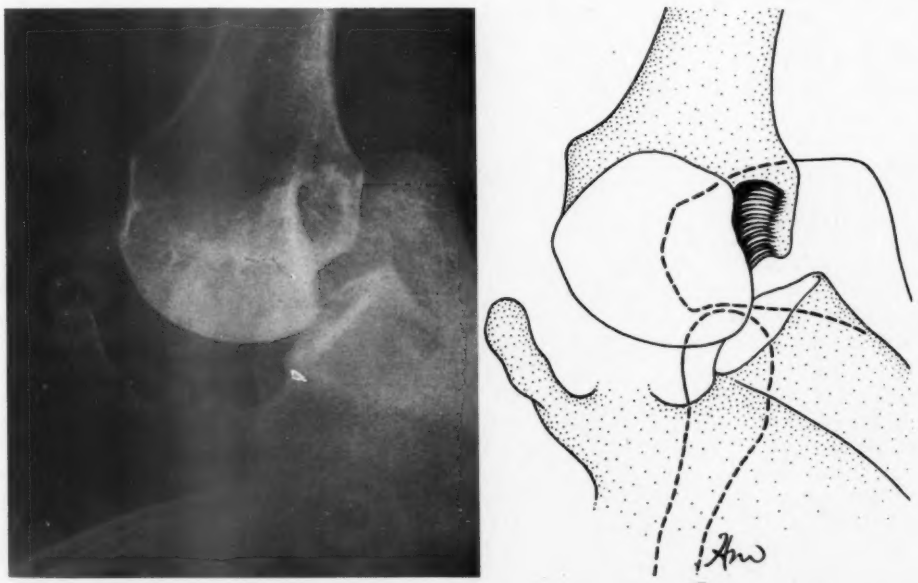
Osseous lesions: (1) Erosion and fragmentation of the anterior bony glenoid rim from primary and recurrent dislocations, formation of loose bodies of bone, cartilage, etc., formation of a false joint on the neck of the scapula in recurrent cases; (2) contusion fracture of the posterolateral aspect of the head resulting in the posterolateral notch on the first dislocation (Fig. 5) or after recurrent dislocations (Fig. 6); and (3) contusion fracture of the anteromedial aspect of the head resulting in the anteromedial notch found in posterior dislocations whether primary or recurrent. (Fig. 7.)

Clinical Picture. The clinical picture of an acute dislocation in the athlete requires little description. There is a history of a fall, twist or blow with the symptoms and signs localized to the shoulder. Often the player feels the displacement of the bones and notes the flattening of the deltoid. The limb is useless and further participation is prevented by pain. In the recurrent cases, the player makes his own diagnosis and often reduces the dislocation himself. Radiological examination should always be made both before and after reduction to demonstrate the possibility of associated fractures and for purposes of record.

The self-reducing subluxation is more difficult to diagnose, and the diagnosis is usually made on the history of recurrent episodes in which the patient feels the bone slip out and in anteriorly or posteriorly. If the patient is seen shortly after the injury, pain will be experienced if the head is manipulated against the anterior

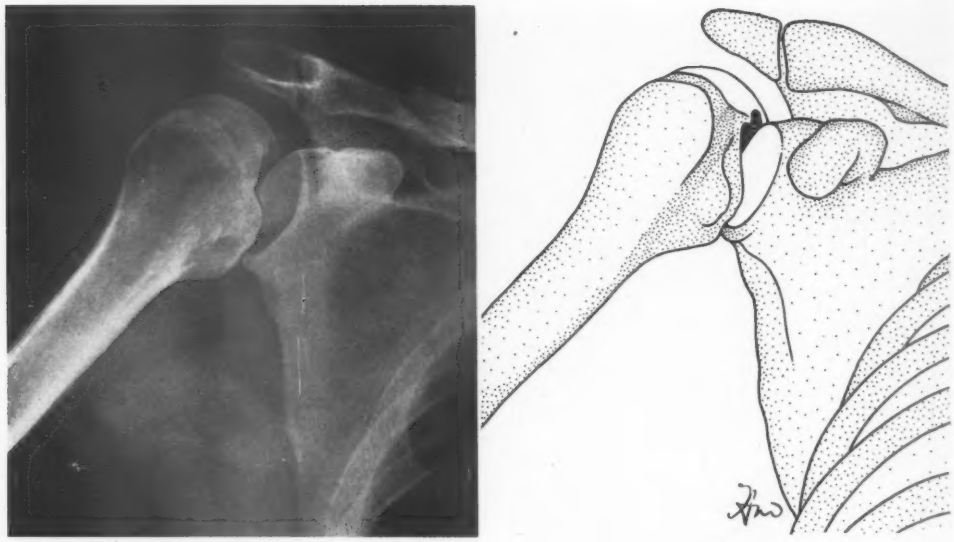
5A 5B

FIG. 5. A, anteroinferior dislocation. B, postreduction film of same dislocation showing the large posterolateral notch produced by the primary dislocation.



6A 6B

FIG. 6. A, superoinferior view of the shoulder in a case of recurrent dislocation. Note large posterolateral notch with diminution in arc of articular surface; also the laxity of the anterior capsular mechanism as indicated by the position of the head and by the axes of the humerus and scapula. Note also calcification of coracoacromial ligament. B, diagram of (A). (Roentgenogram from: MOSELEY, H. F. Shoulder Lesions, 2nd ed. New York, 1953. Paul B. Hoeber, Inc. [24].)



7A 7B

FIG. 7. A, anteromedial notch produced by a primary posterior dislocation. B, diagram of (A). (Roentgenogram from: MOSELEY, H. F. [24].)

or posterior capsule in the respective types. This disorder tends to occur in the loose jointed type habitus.

Principles of Treatment. To restore the joint to complete functional efficiency in the minimal time and to prevent if possible future recurrence are the bases of treatment.

Methods of Reduction. Most surgeons favor one or another method of manipulative reduction. In the acute injury on the playing field, reduction can often be achieved without anesthesia. Kocher's method by rotation [19,24], the fulcrum method with the unbooted heel or fist [14,24], and the hyperabduction method [24,42] all have their advocates. The reduction should be as gentle as possible, enabling the head to return with minimal further tearing of soft tissues.

If the patient is seen later and facilities for general anesthesia are available, less trauma results if the reduction is achieved with adequate muscular relaxation.

Postreduction Therapy. Here differences of opinion certainly exist. Many authors on this continent consider that the young athlete is prone to recurrent dislocation whether the joint is completely immobilized for four to six weeks or not. McLaughlin and Cavallaro [22], Nicola [30], Rowe [33], myself and many others hold this view.

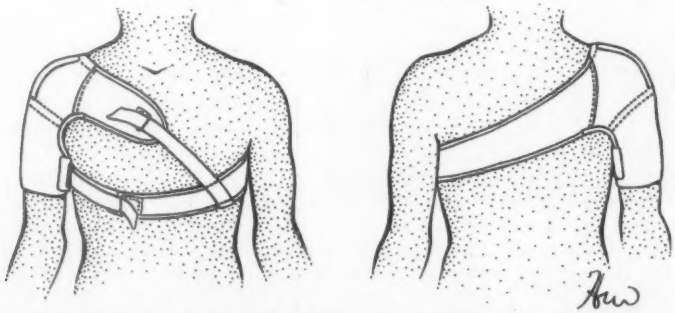


FIG. 8. One of the many types of harness used in cases of recurrent dislocation.

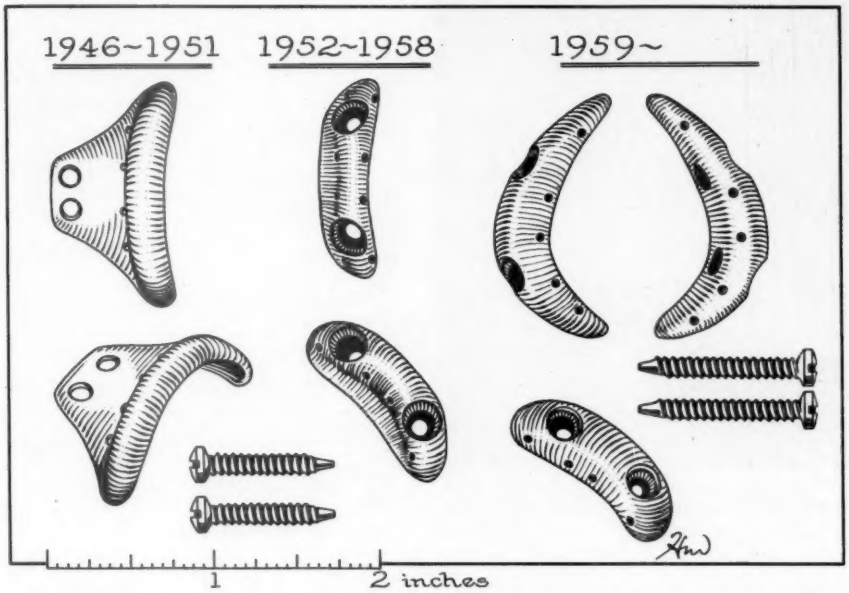


FIG. 9A. Evolution of the Vitallium prosthesis. The latest models consist of a smaller type which can be used in the majority of cases on either shoulder, and a larger model specially designed for the right or left shoulder, which would be selected for the large, heavy-set athlete.

In the case of a primary dislocation in the professional athlete, the player is often permitted to return to competitive sports in seven to ten days. A strapping or harness preventing abduction, forward flexion and dorsal flexion beyond 40 to 60 degrees, is worn. (Fig. 8.)

Ideally, motion beyond this range should be prevented for four weeks and this followed by re-education of muscular power by a program of resistance exercises. It would be significant to evaluate a series of patients treated consistently on this regimen.

In the case of recurrent dislocations, the aforementioned harness should be used in all games and surgery deferred until the off-season period. Most football and ice-hockey clubs have the athletes with recurrent dislocation operated upon in the spring and early summer.

Operative Treatment of Recurrent Dislocation. After the second dislocation and certainly after the third, the only hope for permanent cure rests on operative intervention. As stated previously, the timing of this procedure is determined by the player's activities and should be chosen for the off season.

There is little doubt that great advances in the technical aspects of the procedures have occurred, and there is less tendency now to overtreat these patients so that the joint is left with restricted abduction and external rotation. The idea of so scarring the anterior soft tissues of the shoulder that a fibrous barrier to anterior displacement is created has been altered to the meticulous repair of the anterior soft tissue mechanism. If this is successfully achieved, full range of motion and power is attained.

Most surgeons now perform some type of repair of the anterior capsule. Some are content with the repair of soft tissue [*31,34–37*] while others insist on a repair of capsule to raw bone [*24*]. I favor the latter approach and suture a flap of the anterior capsule and subscapularis to the freshened glenoid rim [*24,26*]. To facilitate this procedure an extra-articular Vitallium® rim is used to hold the sutures. (Fig. 9.) However, the principle is the same whether the result is secured by staples [*10,11*], stainless steel pull out wire, fascia [*12*], etc.

In the postoperative period, early movements below the horizontal plane are permitted and the range above this level is developed after

FIG. 9B. X-ray film showing rim in place. Note large posterolateral defect in this case; also calcification of labrum and periosteum medial to rim from false joint formation.

three to four weeks. No attempt is made to restrict the return to full range even in patients presenting with the large posterolateral defect. I have had five patients with an average follow-up of four years, all of whom presented a large posterolateral notch, and all of whom have a full range of motion without recurrence. The operation enables full return to competitive sports. My series includes athletes in many fields of activity. One professional football player secured the award as best player of the year, and one skier obtained two Olympic world championships following operative repair. (Fig. 10 and Tables I through III.)

TABLE I
RECURRENT DISLOCATION OF THE SHOULDER (125 CASES)*

Location of recurrence:	
Anterior dislocation	124
Posterior dislocation	1
Bilateral dislocation†	6
Postoperative recurrence:	
Operation performed elsewhere (6 cases)	
After Nicola operation	4
After Gallie operation	2
Operation performed locally (4 cases)	
After Nicola operation	1
After Putti-Platt operation	2
After rim applied inferiorly	1

* One hundred nineteen patients including ten epileptic patients treated at Royal Victoria Hospital, 1939 to 1957 inclusive.
† One of these patients had one operation elsewhere.

TABLE II
PROCEDURES (125 CASES)

	Moseley	Others
Bankart with rim:		
Anterior application	65	10
Axillary application	3	
Bankart	22	8
Putti-Platt	1	5
Nicola	2	8
Fascial sling	..	1
Totals	93	32

TABLE III
PROCEDURES (88 RECALLED CASES)*

	No. of Cases	Recurrence
Seen postoperatively (68 cases):		
Bankart with rim	36	0
Bankart	25	0
Putti-Platt	4	3
Rim applied inferiorly	3	1
Not seen postoperatively (20 cases)†:		
Bankart with rim	12	...
Bankart	7	...
Putti-Platt	1	...

* To January 1, 1956.
† Information from answered questionnaire.

Fractures and Fracture-Dislocations of the Upper End of the Humerus

In spite of statements to the contrary, I find that fractures of the upper end of the humerus occur quite commonly in the young athlete in competitive sports frequently associated with dislocation of the joint.

Two groups of fractures of the upper end of the humerus will be discussed, contusion fractures and avulsion fractures.

Contusion Fractures. In this group are included the posterolateral and anteromedial types produced by primary or recurrent dislocations of the head anteriorly and posteriorly, respectively. Different degrees are found, from a stellate fracture without displacement to a deep wedge-shaped compression fracture. The

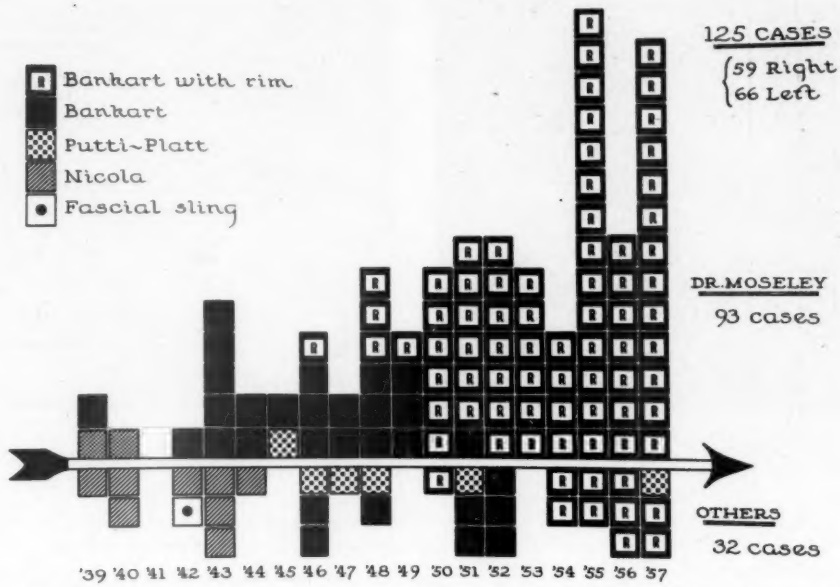


FIG. 10. Operations for recurrent dislocation of shoulder (Royal Victoria Hospital, 1939 to 1957, inclusive).

fracture may occur in association with a first dislocation or only become noticeable on recurrent dislocations. My follow-up on operative repair of the recurrent dislocations discloses the fact that the defect appears to remain permanently, even after further dislocations have been prevented by operative repair. Special roentgenographic views are required to study this defect, and the defect can be visualized and palpated at operation. These defects may lead to formation of loose bodies.

Posterolateral type: This fracture is produced when the posterolateral aspect of the humeral head impinges on the anteroinferior portion of the bony glenoid rim in the final locked position of an anterior dislocation of this joint. (Fig. 5.) As previously stated, it varies from a stellate type fracture without displacement to a wedge-shaped defect of varying depth. The size of the base of the wedge determines the extent of loss of the articular arc of the humeral head. There is no doubt that the presence of a large notch predisposes to the recurrent state.

The defect is well visualized radiologically by anteroposterior views taken in varying degrees of internal rotation, but is still better seen in superoinferior views with the arm abducted 90 degrees and internally rotated varying degrees with 30 degrees as a mean average.

I formerly overlapped the subscapularis to limit external rotation in earlier operations on patients with recurrent dislocation presenting the large notch. In recent years no attempt has been made to limit full movements in spite of the permanent persistence of this mechanical defect, since the Bankart type of repair seems adequately to stabilize the head with this defect present.

Anteromedial type: This defect is produced by impingement of the anteromedial aspect of the head (just posterior to the attachment of the subscapularis on the lesser tuberosity, on the posterior lip of the glenoid fossa in the locked position of a posterior dislocation. Indeed, this defect when seen on radiological examination should immediately suggest a posterior dislocation of the joint. (Fig. 7.) The locking of the head in this manner accounts for the fixation of the arm in internal rotation in these cases, and it requires a fulcrum with lateral leverage to free the head at this point.

This fracture is an incidental finding in posterior dislocation and the treatment is that of the dislocation itself. However, it influences

FIG. 11A. Fracture-disclocation of left shoulder. ([A] and [B] from: MOSELEY, H. F. [24].)

FIG. 11B. Postreduction film showing gross displacement and retraction of greater tuberosity. This case merits open operative reconstruction.

the ease of manipulative reduction and should be taken into consideration during this maneuver.

Avulsion Fractures. Avulsion fractures chiefly involve the greater tuberosity although the lesser tuberosity can be avulsed by the subscapularis in an occasional case.

The avulsion may detach the whole of the greater tuberosity, and the separation extends from the dense compact bone of the outer lip of the bicipital groove backward so that the lesion is really an avulsion of the supraspinatus, infraspinatus and teres minor components of the rotator cuff with the bony attachments on the greater tuberosity. Indeed it is my opinion that a great advance in the general understanding of these lesions would be achieved by designating this lesion a *fracture avulsion of the rotator cuff* rather than a fractured greater tuberosity. The important derangement here is that, in cases of retraction, the rotator cuff and humeral head no longer offer a smooth articulating surface for the coracoacromial arch and this accounts for the limitation of rotation in the subacromial mechanism which so commonly follows this injury.

Avulsions of lesser amounts of the tuberosity, such as the supraspinatus facet alone, also occur and all give much greater disability than is usually expected since any projection on the smooth upper surface of the cuff and head will impinge on the coracoacromial arch from 70 degrees abduction upward.

These avulsion fractures also include contusion type fractures with separation of the fragment and occur in association with anterior dislocations. According to different statistics, fractures of the greater tuberosity complicate up to 20 per cent of anterior dislocations but I would place the figure much higher if both the contusion and avulsion types are included (Table IV.)

The diagnosis is made on radiological examination. When a dislocation is present, detailed views before reduction give information of great value. As in other joints, views in a position of strain will indicate the extent of soft tissue and bony displacement. Postreduction films should be taken to determine the accuracy of the replacement of the bony fragments.

Treatment: There is little discussion necessary regarding the avulsion fractures which reduce to anatomical position following manipulation. In these, the principle of treatment is to allow healing to occur for about three weeks before proceeding to movements of any great

TABLE IV
NOTCH DETAIL IN RECURRENT DISLOCATION (41 CASES)*

	Per cent of Cases
Posterolateral notch present:	
Large	34
Medium	5
Small	48
Posterolateral notch absent	13

* Roentgenographic examinations specifically for notch detail at Royal Victoria Hospital.

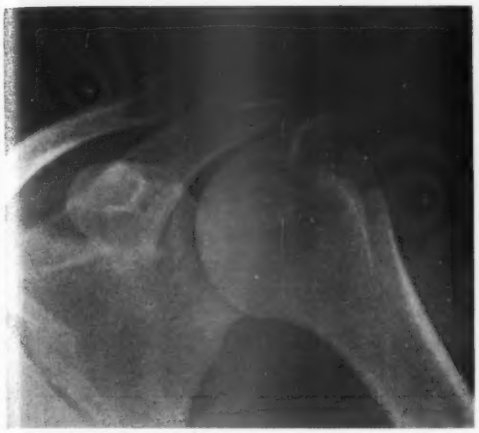


FIG. 12A. Displaced avulsion of supraspinatus facet. (From: MOSELEY, H. F. [24].)

FIG. 12B. End result of conservative treatment of such a case, with permanent derangement of subacromial mechanism.

range. However, if retraction is present after reduction of a dislocation (Fig. 11), or after avulsion has occurred with a self-reducing dislocation, or after pure avulsion, I believe that open operative repair is indicated. My experience with this group on conservative therapy has convinced me that permanent restriction of shoulder motion due to mechanical derangement of the subacromial mechanism persists indefinitely (Fig. 12), and that the best chance of a good result is associated with operative repair at the earliest moment. In the minor avulsions a split deltoid incision will suffice, but in the major fracture dislocations adequate visualization necessitates exposure with detachment of the deltoid through a saber-cut incision with or without section of the acromion. Postoperative therapy consists of early pendulum exercises grading into active elevation of the arm after three or more weeks. I have been impressed by the improved end results achieved by the use of the open operative repair in carefully selected patients.

ILLUSTRATIVE EXAMPLE

Fracture Avulsion of the Cuff with Anterior Dislocation

L. B., a twenty-eight year old man, during a skiing accident dislocated his left shoulder which reduced itself on moving the arm. Roentgenograms showed a fractured greater tuberosity. He regained full function in about two months. One year later, he had a second accident and dislocated his shoulder which was reduced three hours later. Roentgenograms were taken before and after reduction (Fig. 13), after which there was a complete loss of power of abduction. The patient was seen by a neurosurgeon who found no circumflex or other neurological deficit. The patient was referred to me six weeks after the second accident.

Examination disclosed marked atrophy of the deltoid and scapular muscles. There was a complete inability to abduct the arm. The deltoid was active. Surgery through the superior approach with section of the acromion revealed a complete detachment of the supraspinatus, infraspinatus and teres minor with several bony fragments. Considerable retraction was present. Most of the loose fragments of bone were removed and the cuff was resutured into a trough cut in the bed from which the fragments were avulsed.

The patient made an excellent recovery and presented full movements and power on follow-up examination twenty months after operation.

Other Fractures of the Upper End of the Humerus. All types of fractures of this part can occur in the various sports and at the different age groups. Fracture separation of the upper end of the humerus occurs in the ten to fifteen year age group, while fractures of the anatomical, morphological and surgical necks occur with increasing frequency with each

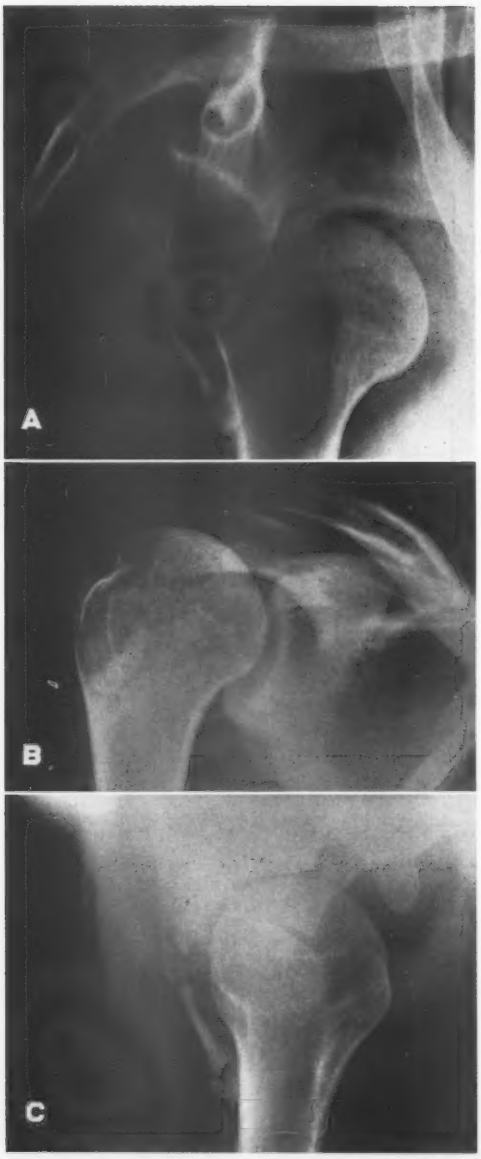


FIG. 13. A, second dislocation of the shoulder with avulsion of the rotator cuff with facets. B, anteroposterior view after reduction. C, superoinferior view after reduction.

decade. No description of these types is necessary except to indicate that the best results are obtained by the use of early movements of the joint, especially in the impacted types.

Scapular Fractures Related to the Glenobumeral Joint

Fractures of the bony glenoid rim and coracoid process may be found in association with anterior dislocations. The former may require modification of the technic of repair when the recurrent state is present. Fractures of the coracoid process caused by direct impingement of the displacing head are rarely displaced and do not require special treatment.

Fractures of the acromion are unusual injuries and are caused by direct blows or by sudden contraction of the condensed middle segment of the deltoid. The periosteum and fused aponeuroses of the trapezius and deltoid on the superior aspect first tear, permitting the fractured segment to hinge downward. All degrees up to complete separation occur.

The diagnosis is made on localization of the clinical signs to this area, and radiological examination discloses the exact site of the fracture and position of the fragments. In the young athlete, the possibility of an ununited acromial apophysis must be differentiated by contralateral x-ray films.

In the fracture without displacement, palliative measures including a sling to support the weight of the limb suffice. In the fracture with displacement, an obvious deformity of the deltoid convexity is present and operative treatment is indicated. Small fragments are removed but a large fragment is best resutured. This will restore the normal coracoacromial arch essential for perfect functional activity of the arm-trunk mechanism.

Various Traumatic Lesions

Attempts to define accurately the exact lesions in this group are limited by the fact that the site of the derangement is usually not visualized for study macroscopically or microscopically. Operative exploration is rarely undertaken, as the disorder usually clears on physiotherapy. Experience through the years has enabled me to see the following groups of cases: (1) rotator cuff and bursal injuries; (2) bicipital lesions; and (3) aggravation of calcified deposits in the rotator cuff.

Rotator Cuff and Bursal Injuries. Rupture of the rotator cuff in the young is unusual, as the strength of the tendon is greater than that of its bony attachment and, therefore, a sprain-fracture usually occurs. Rupture of partial

thickness of the cuff, however, probably occurs in the occasional case, giving the typical supraspinatus syndrome of pain over the abduction range 70 to 120 degrees.

A heavy fall on the point of the elbow can drive the humeral head, covered by the bursa and rotator cuff, against the coracoacromial arch. I have explored such cases in older patients and have found traumatic bursitis and contusion rupture of the superior cuff; I believe that these injuries occur in the younger player and the aforementioned findings explain certain types of cases.

However, complete rupture of a major portion of the cuff is uncommon in the athlete in the second and third decades, although such do occur.

ILLUSTRATIVE EXAMPLE

Complete Rupture of Supraspinatus, Infraspinatus and Teres Minor Tendons

S. S., a 20 year old man, injured his right shoulder three months before operation while playing football. In spite of continuous therapy, the shoulder stiffened on use and he felt a crack in the joint and pain on moving it. He was referred to me as he could not continue participation in football. Examination disclosed a full range of elevation but executed without the normal scapulohumeral rhythm. Rotation of the humerus at 90 degrees abduction produced pain and crepitus. There was tenderness localized to the insertion of the cuff on the greater tuberosity. Detailed radiological examination disclosed a small flake of facet avulsed. At operation, the full thickness of the cuff was found to be avulsed, including the supraspinatus, infraspinatus and part of the teres minor insertions. Some retraction had occurred and the articular cartilage was exposed for 1½ inches in an anteroposterior diameter. The cuff approximated well on abduction and was sutured. Plaster spica with the arm in 90 degree abduction and 30 degree forward flexion was used for six weeks.

The patient made an excellent recovery. At seven months the range and power were judged perfect on measurement and this function has been maintained.

Bicipital Lesions. I have seen acute tenderness localized to the bicipital groove with pain aggravated by movements of the long tendon of the biceps in its sheath in cases in which a direct blow to the area has occurred, or in which the sport has consisted of prolonged use of the shoulder in repetitive motions involving marked excursion of the bicipital tendon. This is seen in skiers, tennis players, baseball players and fencers. The condition subsides rapidly on rest to the part, the application of heat and the systemic use of salicylates and corticosteroids.

Rupture of the tendons of the biceps has not been seen in the young athlete, but fracture-separation of the tip of the coracoid occurs after a direct blow and not uncommonly after anterior dislocation of the humeral head.

Calcified Deposits in the Rotator Cuff. These are occasionally seen in the athletes of the third decade age group, and all the symptoms and signs associated with the acute phase of such lesions develop.

The diagnosis is made on the clinical history of the development of acute pain and limitation in the shoulder movements after a period of unusual activity or after a direct blow. Radiological examination, to be of value, must include anteroposterior views in full internal and external rotation supplemented by superoinferior views. Often the presence of the deposit is not ascertained since pain prevents the proper positioning of the bones to throw the shadow of the deposit away from that of the head of the humerus and acromion.

Treatment will usually be conservative, with the application of cold packs, the enforcement of rest and the systemic administration of salicylates and corticosteroids. I now seldom use infiltration of the area with locally administered anesthetics or corticosteroids. Operative removal of the large deposit is the treatment of choice.

THE CLAVICLE AND ITS ARTICULATIONS

The Clavicle

Fractures of the clavicle are commonly sustained in all impact sports. The site of fracture is most frequently in the body of the bone, next in the lateral quarter, and lastly in the medial quarter.

Anatomical Considerations. The clavicle is shaped with two anteroposterior curvatures, the medial convex anteriorly and the lateral

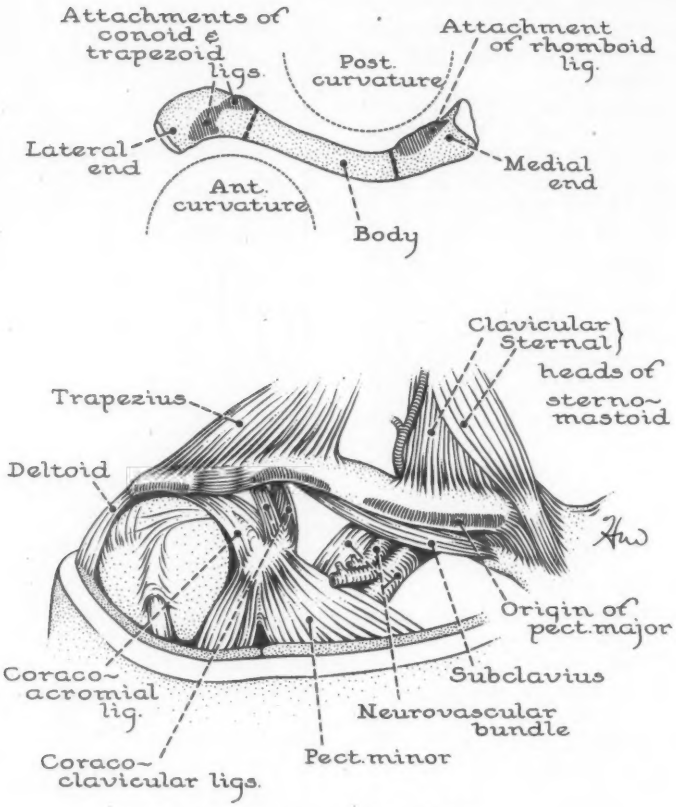


FIG. 14. Anatomy of the clavicle.

convex posteriorly. It is best described as consisting of a body and a lateral and a medial end. (Fig. 14.) It has important relations to the brachial plexus and axillary vessels in the cervicobrachial outlet, and to the structures related to the thoracic operculum. (Fig. 14.)

Mechanism of Injury. The mechanism of injury is usually indirect and follows a heavy fall on the outstretched hand, the point of the elbow or prominence of the shoulder. Direct violence may be occasionally responsible. Fractures of the outer end may be associated with dislocations of the acromioclavicular joint. (Fig. 15.)

Clinical Picture. In the complete fracture occurring in the young adult and involving the body of the bone, the typical deformity consists of the displacement downward, forward and inward of the outer fragment with the shoulder girdle, and the upward displacement of the medial fragment by contraction of the sternomastoid.

There is usually an obvious deformity, with localized tenderness and crepitus on palpation. Radiological examination will demonstrate the nature of the fracture and the position of the fragments.

Treatment. Fractures of the medial end do not usually present displacement because of the protection of ligamentous and muscular attachments. A sling for a short period usually suffices.

Fractures of the lateral end are of three types: (1) Those through the clavicle at the attachment of the coracoclavicular ligaments. These usually do not displace, and require minimal support. (2) Those involving the acromioclavicular joint. If interference with the joint mechanism is present, excision of the outer end is indicated. (3) Those in the

FIG. 15. Fracture of the outer end of the clavicle with rupture of conoid and trapezoid ligaments. Note increased coracoclavicular spacing. This patient could be treated by excision of the outer end of the clavicle and repair of the coracoclavicular ligaments.

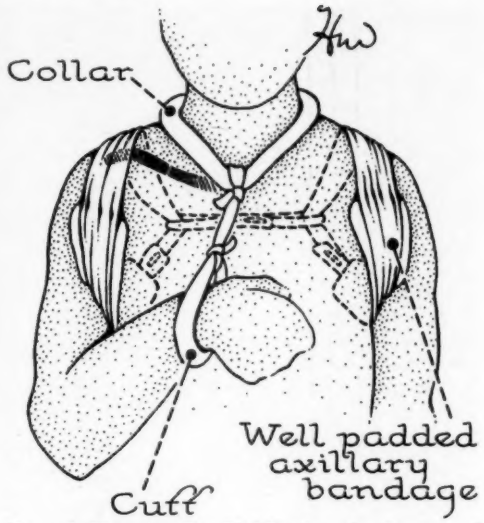


FIG. 16. Three-handkerchief bandage for fracture of clavicle.

lateral end between the attachment of the coracoclavicular ligaments and the joint. When these are complete, they present the same deformity as do those involving the body. Such are difficult to maintain in the corrected position and usually unite in a position of 90 degree rotation forward and medially. The functional results are excellent after treatment by the three-handkerchief method.

Fractures of the body are treated by the three-handkerchief bandage (Fig. 16), figure eight plaster cast, or the clavicular cross. Reduction is achieved by bracing the shoulder girdle upward and backward. A sling or collar and cuff is also applied. Immobilization of patients in their athletic years varies from four to six weeks and loss of time from sports ranges from six to eight weeks. In certain cases in which reduction is prevented by the interposition of soft tissues, the use of an intramedullary wire after open operative reduction may be indicated.

The results of treatment are excellent when assessed on a functional basis. However, anatomically speaking, a considerable deformity often persists. Non-union is rare but may occur after either conservative or operative treatment. It is best treated by freshening the bone ends, intramedullary fixation, and packing with cancellous bone chips. Malunion may produce the syndrome of costoclavicular compression.

The Acromioclavicular Joint

Mechanical derangements of the acromioclavicular joint account for a considerable proportion of the injuries of the shoulder region sustained in athletic pursuits. Subluxations and dislocations of this joint are frequently designated as "shoulder separations."

In practice the following types of lesions may be differentiated: (1) minor sprains and contusions, (2) subluxations, (3) dislocations, and (4) traumatic arthritis including internal derangements.

Anatomy of the Joint. This joint presents great variability in its anatomical structure which can be best described under various headings:

Type of facet: The facet on the outer end of the clavicle varies greatly in size, shape and inclination. Figure 17 shows the different types of facets found on radiological examination [*24,39*]. In my experience, the vertical and underriding types appear to be most prone to prolonged disability after injury.

DePalma [*8*] has pointed out that a series of clavicles showed different degrees of anterior torsion of the lateral third of the bone, and that the degree of torsion determines the angle of inclination of the articular surfaces at the acromial and sternal ends.

Capsule and musculotendinous attachments: The clavicle and acromion are held together

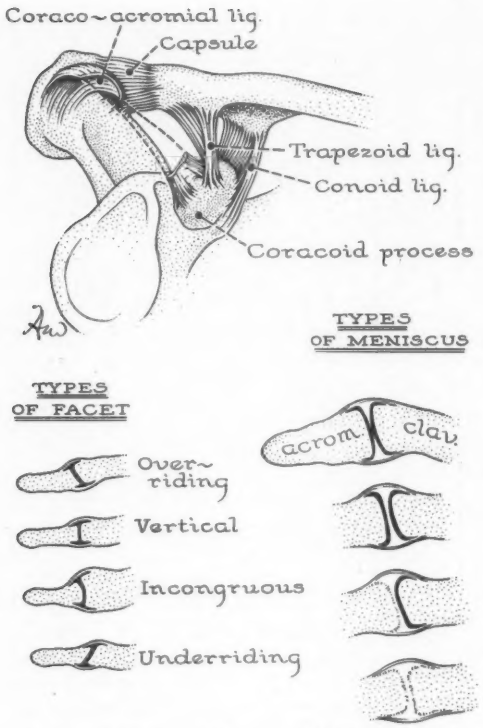


FIG. 17. Anatomy of the acromioclavicular joint.

by a capsule which is greatly strengthened superiorly by the interwoven fibers of the deltoid and trapezius attachments to the capsule, adjacent periosteum and bone.

Intra-articular meniscus: The joint presents a variable type of meniscus (Fig. 17), which is much less developed than that found in the sternoclavicular joint. Unlike the latter disk, the meniscus in the acromioclavicular joint is especially prone to degenerative changes. In my series of fifty-one anatomical specimens studied [*24*], 40 per cent showed evidence of a fibrocartilaginous disk or remnants thereof. However, I noted that cadaveric material was very poor for such studies. Repetition of this investigation on twenty fresh subjects at autopsy showed partial or complete rings of fibrocartilage in all the forty joints dissected. DePalma's studies [*8*] revealed complete disks in 8.6 per cent and partial disks in 10.3 per cent of 223 sets of cadaver joints examined.

Lesions of these intra-articular fibrocartilages will explain certain symptoms and signs referable to this joint following injury.

Coracoclavicular ligaments: The conoid and trapezoid ligaments bind the clavicle to the coracoid process and afford additional strength to the acromioclavicular joint. Their rupture, in complete dislocations, permits the marked upward displacement of the outer end of the clavicle and is evidenced on roentgenograms by increased coracoclavicular spacing. (Fig. 18.)

Function of the Joint. The acromioclavicular joint is one of the components of the complex arm-trunk mechanism and permits a gliding motion in an upward and downward, a forward and backward, and in a rotatory manner. This movement accounts for approximately 20 degrees of the full elevation of the arm; and operative procedures to fix the clavicle rigidly to the scapula either at the joint itself, at the site of the coracoclavicular ligaments, or both, have been largely abandoned because of their tendency to restrict full elevation of the limb. The work of Mollier [*23*] and Inman and Saunders [*15*] has greatly assisted our understanding of this mechanism. However, Kennedy and Cameron [*17,18*] note that this is chiefly seen in patients over fifty years of age in whom compensatory adaptation to the changed mechanics fails to occur.

Experimental Studies on the Joint's Stability. Experiments by Cadenat [*7*], Urist [*39*] and others have demonstrated that complete dislocation of the joint occurs after section of the capsule and coracoclavicular ligaments, which finding conforms with clinical experience. Section of the capsule and overlying muscular attachments permits subluxation and dislocation without much overriding, whereas section of the conoid and trapezoid ligaments alone does not permit displacement at the joint.

The Clinical Picture. The patient may present an indefinite syndrome, with pain and limitation of the arm-trunk movements, which requires careful examination to be diagnosed as a lesion of the acromioclavicular joint; or there may be a history of a severe impact on the acromial aspect of the shoulder with some prominence of the outer end of the clavicle as found in subluxation, or with marked prominence as found in complete dislocation.

If the localization of the pain by the patient is indefinite, the following two tests have been found valuable: (1) The patient is asked to place the hand of the affected side on the

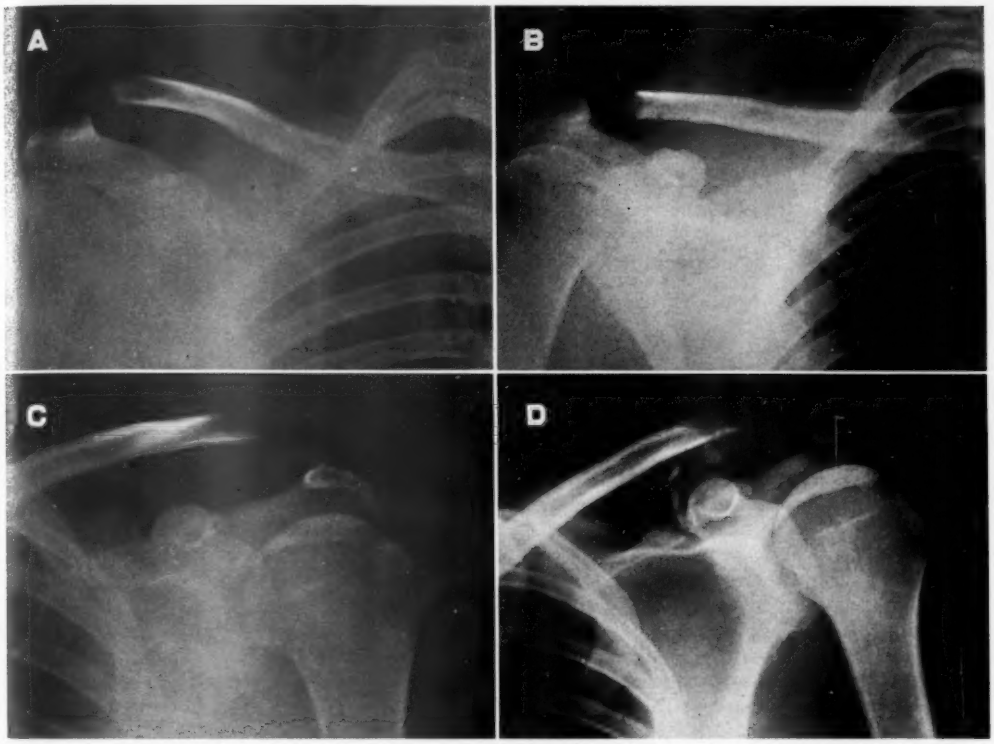


FIG. 18. A, complete dislocation of the right acromioclavicular joint. Note increased coracoclavicular spacing. B, same case after excision of the outer end of the clavicle and fascial repair of coracoclavicular ligaments. C, neglected case of acromioclavicular dislocation in a professional hockey player. Note heterotopic bone formation. D, follow-up of same case two years after excision of outer end of clavicle and reconstruction of coracoclavicular ligaments, necessitated by pain and discomfort. ([A] and [B] from: MOSELEY, H. F. [24].)

opposite shoulder. The examiner then presses the elbow strongly to the opposite side. This will increase the pain in recent acromioclavicular injuries, and palpation over the posterosuperior aspect of the joint will elicit acute tenderness. (2) The patient is asked to go through the circumduction movements necessary to throw a ball overhand. In severe injuries, this effort will be too painful. In lesser injuries, the repetition of this exercise will enable the examiner to localize the site of derangement to this joint.

In the case of subluxation, local tenderness and the prominence of the outer end of the clavicle are conclusive. This is even more obvious in cases of complete dislocation, in which the displacement can be reduced by downward pressure on the clavicle and upward replacement of the shoulder girdle by pressure at the elbow.

Radiological examination of both joints on the same film with downward traction on the limbs (25 pound weight) will demonstrate the disruption of the joint and the increased coracoclavicular spacing. (Fig. 18.)

Treatment. There is little difference of opinion regarding the treatment of minor sprains, contusions and subluxations. Cold compresses and a sling in the early stages, with the application of heat, and massage and early movements after the first day will give rapid relief. A protective strapping and shoulder pad should be used when early return to sports is contemplated. When discomfort on overuse tends to be recurrent, intraarticular injection of hydrocortisone can be tried. Failure of relief due to traumatic arthritis and internal derangement of the joint will indicate resection of the outer end of the clavicle in the occasional case.

A great difference of opinion appears to exist

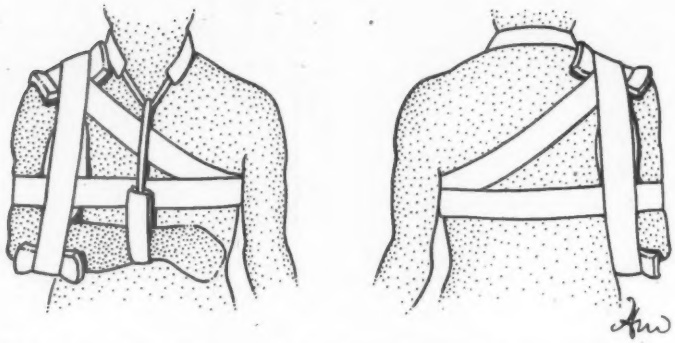


FIG. 19. One type of bandaging for acute dislocation of acromioclavicular joint.

in the treatment of complete dislocations and a variety of procedures has been advocated.

Possible procedures: (1) Conservative bandaging. (Fig. 19.) If this fails, operative repair is indicated; (2) fascial repair of joint and coracoclavicular ligaments (Bunnell [6]); (3) longitudinal fixation of the joint with wire (Murray [28] and Phemister [32]); (4) coracoclavicular screw (Bosworth [5], Kennedy [18] and Vere-Hodge [41]); (5) suture of the joint with repair of coracoclavicular ligaments by the short biceps tendon (Vargas [40]) and the coracoacromial ligament (Neviaser [29]); (6) excision of the outer end of the clavicle (Gurd [13] and Mumford [27]); and (7) excision of the outer end of the clavicle and repair of the coracoclavicular ligaments (Moseley [24]).

Personal Practice. Before 1946 I used various procedures for the repair of capsule and coracoclavicular ligaments. Follow-up roentgenograms showed that when wire was used, breakage of the wire frequently occurred if full movements were restored.

Since 1946, the Gurd-Mumford procedure has been used, i.e., excision of the outer end of the clavicle distal to the angle, approximately ¾ inches. At first this alone was performed. However, the outer end of the sectioned clavicle tended to displace upward and backward and to give pain from pressure on the trapezius. Suture of the end of the clavicle to the coracoid with braided silk or nylon was then practiced; this has now been supplemented with a fascial suture. (Fig. 20.)

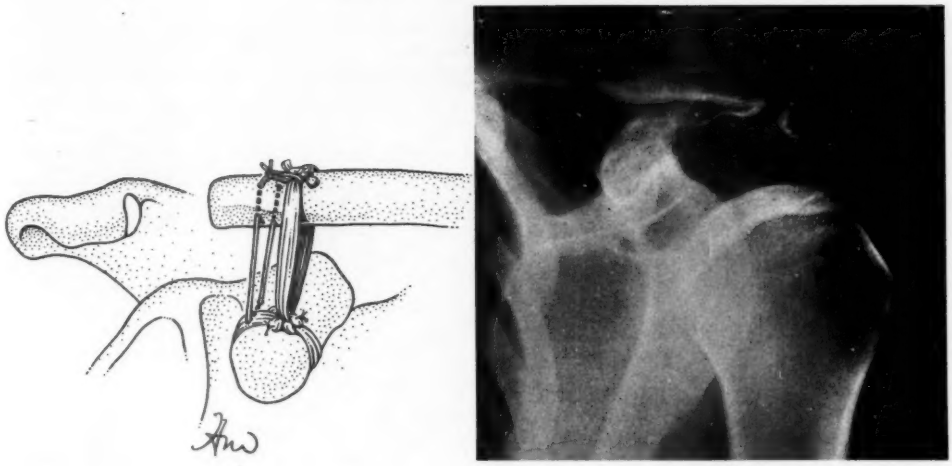
Selection of Time for the Operation. There is a difference in the choice of operative treatment and the timing thereof in the case of the professional as compared with the amateur athlete. The former is under contract with a club, and it is usually contrary to both the athlete's and the club's interests to advise operative treatment with the necessary prolonged layoff during the season, or even during the years of professional activity. Hockey and football players can carry on without great discomfort with a dislocated acromioclavicular joint. Protective pads can be used during the games. The cosmetic factor and the inconvenience of discomfort as a late sequela can be left for later correction.

Amateur athletes often prefer operative correction at the time of the acute dislocation. Naturally each case must be decided after a careful presentation of the problem to the individual concerned.

Results. The results of early operative repair by my method have been most satisfactory. There is a full range of motion and full power as tested at 90 degree abduction and 90 degree forward flexion. My personal series consists of twenty-eight cases. There have been no infections or complications of note.

Kennedy [17,18] prefers the use of a lag screw fixing the clavicle to the coracoid and has kindly summarized his experience for me as follows:

"We are still completely convinced that this is the operation of choice in the complete acromioclavicular dislocation in an active workman or a competitive athlete. I know of no other procedure that will return an athlete to competitive sports in so short a period of time as this operation. If properly performed the immediate and remote complications are few in number. We still believe



20A 20B

FIG. 20. A, my present operative approach for complete dislocation of acromioclavicular joint. B, follow-up of a case of fascial repair of coracoclavicular ligaments without excision of end of clavicle, two years after operation. Note calcification of inferior capsule of acromioclavicular joint and early signs of degenerative arthritis. This patient had a full range of movement of the shoulder mechanism.

that we are producing an extraarticular fusion of the acromioclavicular joint and we have not had to remove one screw nail in any of these 46 cases. We feel that this operation should not be performed in anyone over 50 years of age since the patients over this age do not seem to be able to adapt themselves to the synchronous scapuloclavicular rotation that occurs in the younger age group. In selecting these patients we feel that there is no difficulty with the complete dislocation, but if one is still puzzled as to whether this represents complete dislocation or not, then inability to abduct the arm past 90° at the end of one week, we feel, probably represents a complete dislocation. We have found no case in which the conoid and trapezoid ligaments were not completely torn at the time of operation.

"Of the 46 results, 7 were indifferent. We say that they were indifferent as they were not failures but still had pain and some limitation in movement of their shoulders. We have performed this operation on many medical students, injured in interfaculty sports and see these boys around the hospital far in the future. I have not talked to one of them who has been unhappy with the procedure. For us it is the operation of choice."

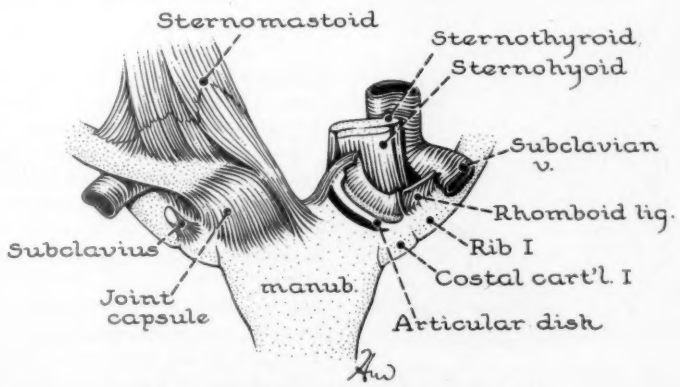


FIG. 21. Anatomy of the sternoclavicular joint.

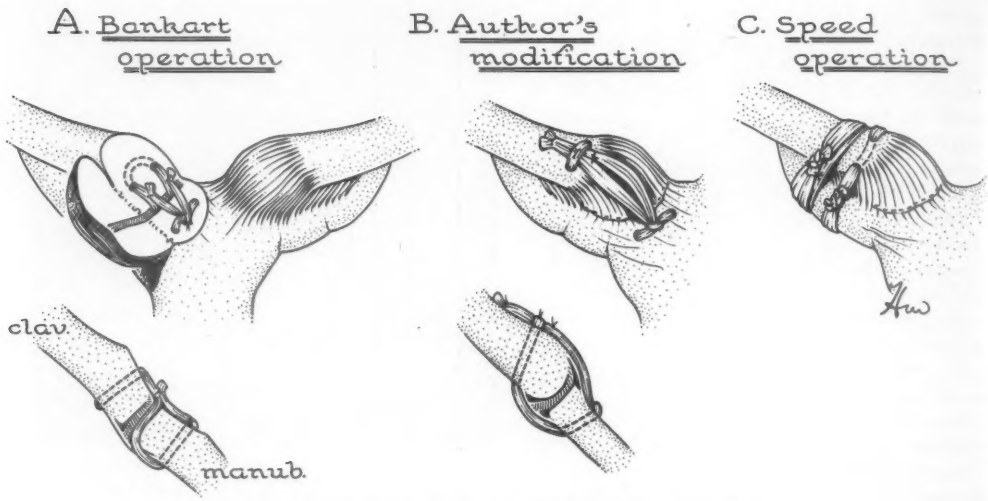


FIG. 22. Types of fascial repair for sternoclavicular dislocation.

The Sternoclavicular Joint

Injuries of this joint are much less common than those of the acromioclavicular joint. Complete dislocations give rise to great pain and if left unreduced are disabling during most athletic activities.

Types of Lesion. (1) minor sprains and contusions; (2) subluxations, usually anterior; (3) complete dislocations, anterior, superior and retrosternal; and (4) recurrent dislocations of the sternal end of the clavicle or of the intra-articular disk.

Anatomy of the Joint. This is a stable articulation and one not prone to injury or disease. The joint space is divided into two compartments by a strong intra-articular fibrocartilage which is occasionally perforated in the older patient. The disk is strongly attached superiorly to the sternal end of the clavicle, and this arrangement explains why, in dislocations, the fibrocartilage usually displaces with this bone. (Fig. 21.) The stability of the joint is determined by the strong capsular ligaments, reinforced inferiorly by the costoclavicular (rhomboid) ligament. Additional support is afforded anteriorly by the sternal head of the sternocleidomastoid muscle, while posteriorly the sternohyoid and sternothyroid muscles serve as a protection to the great vessels when the clavicle is dislocated posteriorly. The major venous and arterial structures related to the posterior aspect of this joint are the important anatomical considerations in operative procedures on this articulation.

FIG. 23. Unusual result after excision of inner end of clavicle. Note fusion to first rib. (Courtesy of Dr. Arnold Noble.)

Function. This joint affords the only articulation of the upper limb with the trunk. It is concerned in all movements of the arm-trunk mechanism but its function is best demonstrated in the movements of the shoulder girdle alone, i.e., (1) elevation or shrugging, (2) depression, (3) protrusion, (4) retraction or bracing, and (5) circumduction, which is a combination of the first four.

Increased motion occurs at this joint as a compensatory mechanism in disorders asso-

ciated with stiffness in the glenohumeral or acromioclavicular articulations.

Mechanism of Injury. Some years ago I studied the production of dislocation of this joint on the fresh cadaver. It was soon discovered that this is an exceptionally strong joint and that dislocation is difficult to produce. The anterior dislocation results from a forcible retraction of the shoulder girdle with an associated lateral compression force. The posterior dislocations occur with the girdle in elevation and protrusion with an added lateral compression force. This type can also be produced by a direct blow in an upward and backward direction. In studying the histories of wrestling and football accidents producing these dislocations, it is found that the added element of a lateral force compressing both shoulder girdles is usually present. The forward dislocation has been produced by a force moving the abducted arm suddenly behind the coronal plane as occurs in wrestling.

Clinical Picture. The symptoms and signs will vary with the severity of the accident and the extent of the displacement.

Minor sprains, contusions and subluxations are characterized by local swelling and tenderness over the joint, and pain on movement of the limb.

Anterior dislocations are readily diagnosed by the prominent swelling over the sternum which is reduced by bracing the shoulder backward and retained by direct pressure backward on the sternal end of the clavicle.

Posterior dislocations are much less common and may produce symptoms of pressure on the great vessels, trachea or esophagus.

Treatment. Minor injuries subside on palliative therapy. Complete dislocations, however, present a problem in early decision. In my opinion, all such cases merit operative procedures to maintain reduction since it is so difficult to prevent redisplacement by splinting and bandaging after manipulative reduction. The fascial repair of Bankart (Fig. 22A) in a modified form (Fig. 22B) has been successful in my hands although a slight degree of anterior subluxation usually persists. Others have used the Speed repair. (Fig. 22C.) In the neglected patient with persistent pain, resection of the sternal end may be undertaken. This sometimes results in excessive replacement of bone in the young patient. (Fig. 23.)

In the retrosternal dislocation [*16*], great care should be taken in the reduction and this should only be performed in the operating room. Reduction may disclose or cause injury to the large venous channels and facilities for their emergency treatment must be available.

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Anterior dislocations of the shoulder, 1949. By Moseley, H. F. Running time, forty-one minutes; silent; color.

Surgical anatomy of the shoulder, 1949. By Moseley, H. F. Running time, forty-five minutes; silent; color.

Inferior relations of the shoulder joint, 1950. By Moseley, H. F. Running time, twenty-one minutes; silent; color.

Recurrent dislocation: repair of the anterior capsular mechanism using a Vitallium glenoid rim, 1958. By Moseley, H. F. Running time, thirty-five minutes; sound; color.

* All these films can be obtained from the American Cyanamid Company, Surgical Products Division, Danbury, Connecticut.

The Treatment of Dislocations of the Acromioclavicular Joint

A SURVEY OF THE PAST DECADE

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ALTHOUGH the acromioclavicular joint is only an accessory part of the shoulder girdle, it presents a formidable challenge in surgery of trauma. Nicoll [1] wrote an interesting editorial entitled, "Miners and Mannequins," in which he observed that it is the mannequin rather than the coal miner who poses the problem of the acromioclavicular disolcation. The coal miner did not require correction of the dislocation and had no disability following this injury. The mannequin needed correction of the dislocation and a perfect cosmetic, pain-free end result. Nicoll also observed that this has been accomplished in the past by extensive surgical operations producing large or conspicuous scars on the most prominent parts of the shoulder. In 1946, I [2] reviewed the literature (101 references) dealing with all conservative and surgical methods of treatment. To bring the subject up to date, this communication will review articles that have appeared from 1946 to 1958. Combined, the old and the recent reports include a large number of very good non-operative methods of treatment of dislocation of the acromioclavicular joint. These fail in actual practice mainly for one reason: the extent of the traumatic lesion is underestimated and not enough time and effort are invested in construction of an efficient splint. The splint must be designed to immobilize to a degree commensurate with the degree of the damage to the shoulder. The individual patient as a person, his social position, age, occupation, ability to cooperate in treatment all should be taken into consideration.

Traumatic Lesion. Dislocations of the acromioclavicular joint occur as a result of rupture of three groups of ligaments in the following sequence, causing three degrees of injury: first, the acromioclavicular joint capsule and ligaments; then, the clavicular origins of the deltoid and trapezius muscles; and last, the coracoclavicular ligaments. I emphasized the leading role of the muscle attachments and the acromioclavicular ligaments and the secondary importance of the coracoclavicular ligaments. Horn [3] observed that the persistent pain and weakness following the injury was caused by tearing of the trapezius and deltoid muscles. Notwithstanding the validity of these findings obtained by direct observation at open operations on the shoulder, surgical procedures, based upon principles erroneously aimed at restoration of the coracoclavicular ligaments without regard for the joint capsular ligaments, are still in use and subject the patient to illogical treatment and prolong his convalescence.

Motorcycle, parachute jumping, and high-speed auto accidents frequently produce the great force necessary to cause complete dislocations. College sports and slip-and-fall accidents frequently cause incomplete and not complete dislocations. Our experience has shown a ratio of 6 incomplete to 4 complete tears in patients in "normal" American urban life.

Conservative Treatment. Approximately fifty different designs of strappings, splints, harnesses, braces or casts have been made to cor-

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TABLE I

THREE DEGREES OF INJURY AND THIRTY-TWO METHODS OF CONSERVATIVE TREATMENT OF INJURY TO THE ACROMIOCLAVICULAR JOINT

Traumatic Lesions	Methods and Authors	Principle and Function
Incomplete tear, acromioclavicular joint capsule and ligaments	Slings and Bandages: Pilcher Desault Velpeau Jones Lund Adhesive Dressings and Strappings: Stimson Sayre Nickols & Smith Gordon Martin Watson-Jones Thorndike & Quigley	Depresses the distal end of the clavicle
	Suspension: Barr Metz & Caldwell Braces and Harnesses: Currie Warner Rawlings Giannestras Shaar & Howard Batchelor Varney et al. Brandt	Either depresses the clavicle or elevates the scapula, or both
Complete rupture of the acromioclavicular joint and capsule and incomplete tears of the coracoclavicular ligaments	Casts: Hunkin Gibbins Key & Conwell Hart Bohler Trynin Legg Dillehunt Morrison	Either depresses the clavicle or elevates the scapula, or both
Complete rupture of the acromioclavicular and coracoclavicular joint	Urist	Depresses the clavicle below the level of the elevated scapula

References to the literature on devices listed above can be found up to 1946 [2] and from 1946 to 1958 in the bibliography of this communication.

rect the deformity and immobilize the acromioclavicular joint. These range from the neatest and smallest to the largest and most grotesque seen in the whole field of traumatic and orthopedic surgery. The extraordinary range of motion, small size, and the anatomical relationship to the chest and shoulder girdle, all combine to make this joint very difficult to immobilize. Of course, this is also the reason that it is important to determine how much damage has been done to the ligaments that normally maintain the relationship of the joints of the shoulder, and how much supplementary external immobilization is required to retain the normal position of the clavicle. The principle of the acromioclavicular immobilization is as follows: the acromioscapular part of the joint must be elevated while the clavicle is being

pressed downward. The best results have been obtained when the splint depressed the clavicle below the level of the acromion process. Fragments of meniscus or ligament may become folded up inside the joint and obstruct relocation of the clavicle but this is a rare occurrence. Three degrees of damage or types of injury to the acromioclavicular joint, and the methods of conservative treatment that can be used for each one, are listed in Table I. The references to the original literature can be found in a previous communication [2].

Incomplete tears, in which the clavicle is not displaced upward out of the joint and the acromion is not pulled downward by the weight of gravity, should respond to the strappings described by Sir Robert Jones and Thorndike and Quigley. We have supplemented this with an arm sling tied up high to elevate the scapula. Many other methods can be useful if diligently applied in the case of a cooperative patient. All can be expected to be effective in patients with first degree injuries or incomplete dislocations of the acromioclavicular joint capsule and ligaments. It is unlikely, however, that complete tears, second or third degree injuries, can be reduced and immobilized by anything except a splint that does two things at the same time: (1) elevate the scapula, and (2) press down the outer end of the clavicle. Nothing has been more efficient than a non-removable stationary plaster for this purpose.

Since 1946, at least five new splints have been designed to hold the clavicle in full contact with the acromion process. Gibbens [4] devised a variation of the hanging cast.* Morrison [5] employed the principle of an axillary crutch. Batchelor [6] constructed a universal corset splint reinforced with aluminum that elevated the shoulder and immobilized it not only for dislocations of the acromioclavicular joint but also for fractures of the clavicle. Varney, Coker and Cawley [7] invented a new harness. Brandt [8] also improvised a new splint. Jud [9] reviewed the principles of conservative treatment and Chigot, Rougerie and Bouffard [19] tested the Urist's plaster-and-elastic apparatus and concluded that it was a "good orthopedic solution" for complete dislocations.*

Surgical Anatomy. Abbott, Saunders, Hagey and Jones [11] reviewed the literature and the surgical anatomy of the acromioclavicular joint in relation to the shoulder girdle. The extent of the exposure that was necessary to repair both the acromioclavicular and the coracoclavicular joints was so formidable that only the most extensive dislocations can possibly warrant so much treatment. Gardner [13] recently reviewed the embryogenesis and Alexander [12] described the roentgen anatomy. The shape of the clavicle and the acromion process showed extraordinary individual variation. The distal end of the clavicle usually lay parallel to the articular surface of the acromion process, but it sometimes rode above it, and in rare instances it slid under it [2]. Codman [14] suggested that the action of the clavicle was to hold the head of humerus and glenoid in a lateral position on the chest wall like a rod that holds the ring in the bull's nose. When the clavicle has been dislocated and unable to perform this function, the shoulder drops forward and to a slightly inferior position on the chest. At first, this is a painful mechanical situation; later, after the acute inflammation of injury subsides it has surprisingly little effect on the range of motion or power of the muscles of the shoulder girdle.

Surgical Treatment. Thirty different surgical procedures, based on one of five different principles, have been described in the literature: acromioclavicular suture, coracoclavicular fixation, coracoclavicular suture, ligamentopexy, excisional surgery. All are now in common use for treatment of complete dislocations of the acromioclavicular joint. The relatively large number of different procedures has been interpreted as evidence that no one is satisfactory. It is also likely that some of the cases subjected to surgery in the past were not always given an adequate trial of treatment by a conservative method. An old and honored dictum of surgery is that the most conservative procedure may be the best and often should be used first. This is especially wise when the end results of surgery generally leave something to be desired. The reasons generally given for surgical treatment of the acromioclavicular joint is that it is small and difficult to immobilize for a period as long as the six weeks required for ligaments to heal. The five main surgical procedures now in common use are shown in Table II. Each one of these

* Early in 1959, after the period covered by this review of the literature, Stubbins and McGaw (*J.A.M.A.* 167: 672, 1959) modified the suspension cast to make it tilt upward against the axilla on the side of the dislocation, and claimed uniformly excellent functional and cosmetic results at short term follow-up examinations of twenty-three patients.

TABLE II
THE FIVE MAIN SURGICAL PROCEDURES NOW IN COMMON USE

Method	Additional External Immobilization	Complications
Acromioclavicular transfixation wires or screws	Yes	Migration of wire
Coracoclavicular transfixation screw	No	Ossification of coracoclavicular ligaments
Coracoclavicular wire ties	Yes	Fracture of wires
Acromioclavicular and coracoclavicular lashing with fascia (ligamentopexy)	Yes	Stretching and failure of fascia
Excision of the outer end of the clavicle	No	Protrusion of the stump of the clavicle

has its own limitations and no one is entirely satisfactory. The over-all end results, however, are unknown in a significantly large series of cases in any operation except for excision of the outer end of the clavicle.

Uninterrupted immobilization for six weeks in the splint shown in Figure 1 can be considered a complete trial of conservative treatment. Only if this course fails, and only if the patient is a person who requires or requests a perfect cosmetic result is it necessary to advise surgical treatment. While the number of cases requiring surgical treatment is relatively small, there were three times as many articles on surgical treatment as on conservative treatment during the past decade [*5–28*]. This list of references is probably not complete and includes only those published in English, French and German readily accessible to the writer, but there were equally as many good articles in journals published in Italian, Spanish, Russian and other languages that can be obtained from the Armed Forces Medical Library in Washington.

Before World War II, Vere-Hodge introduced the coracoclavicular screw [*2*] to hold the clavicle as close as possible to the coracoid process, while the ligaments could heal; interest in this method has been sustained during the past ten years [*21,25,29–32*]. It was and still is opposed, however, by many observers because it prevents the clavicle from rotating on its long axis. Kennedy and Cameron [*32*] defended the method with the contention that the clavicle and scapula moved and rotated synchronously on the chest wall after screw fixation, and observed that it did not interfere with abduction of the arms. The unphysiological character of this method, however, is apparent in postoperative roentgenograms showing corrosion of the bone around the screw. The screw had to be removed in some cases because of pain, arising six to eight weeks after the operation. Dohn [*26*] added a washer and nut to prevent corrosion of bone. Perschl [*28*] and Orofino and Stein [*34*] recommended either coracoclavicular or acromioclavicular loops of wire, or both, for internal fixation. Böhler [*33*] revived the old Phemister technic of an acromioclavicular pull-out Kirschner wire. The shoulder girdle does not appear to tolerate this treatment any better than the coracoclavicular screw, judging from the frequency with which the wires migrate or break in many cases as soon as there is any appreciable movement of the shoulder girdle [*2*]. Odelberg [*20*] devised an extra-articular method of wiring to avoid this difficulty.

The large ligaments of the acromioclavicular joint, like those of the knee joint in athletes, have been sutured as soon as possible after injury. This has been accomplished recently with and without fascial or ligamentous transfers [*22,28*]. The results have been successful in some instances, but such treatment required the usual long and arduous period of convalescence in splints, which, if correctly applied, may have been sufficient alone and without surgery to produce satisfactory repair. In ten cases of dislocation of the acromioclavicular joint at the UCLA Student Health Service seen by me in the ten-year period from 1948 to 1958, eight were incomplete, and two were complete dislocations. The eight patients with incomplete dislocations, so-called subluxations of the acromioclavicular joint, were treated by the adhesive strapping of Thorndike and Quigley [*10*], and a sling. One patient with complete dislocation, treated by my splint had a perfect end result. (Fig. 2.) One patient was untreated for two weeks before he appeared for medical advice; he was referred to the Wadsworth Hospital (U. S. Veterans Administration Medical Center at Los Angeles) for surgical excision of the outer end of the

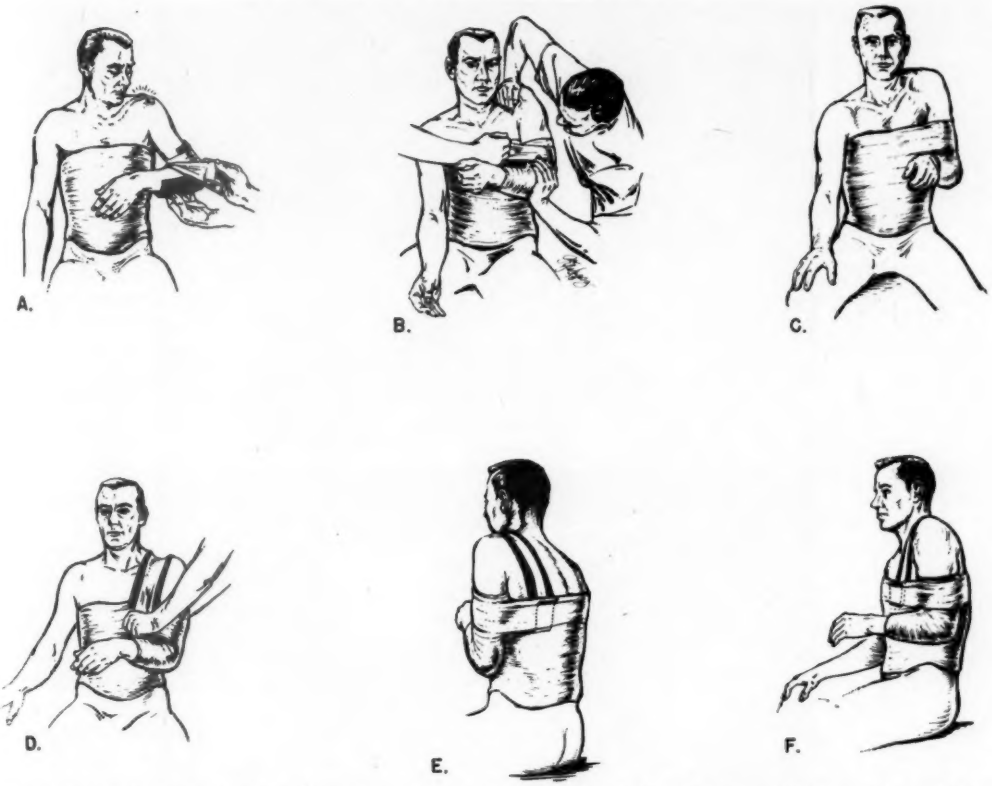

FIG. 1. Artist's interpretation of various stages of construction of the author's splint: A., a cylinder cast is applied to the torso, correctly padded over the iliac crests to bear weight; a cyclinder cast is applied to the ipsilateral elbow correctly padded on the dorsal aspect to withstand pressure; B., to elevate the acromion, the arm is pushed upward while the elbow cast is attached to the lateral aspect of the torso cast; C., the entire shoulder including the scapula is immobilized in an elevated position supported by the iliac crests; D., after a felt pad is placed over the dorsum of the shoulder, the outer end of the clavicle is depressed with the use of a strip of rubber (obtained from the inner tube of an automobile tire); E., by stretching the rubber strip over the clavicle and folding it back on itself in plaster, the clavicle becomes depressed against the coracoid and acromion processes; F., completed splint showing the simultaneous elevation of the shoulder and depression of the outer end of the clavicle in the overcorrected position.

clavicle. Nearly all of the patients admitted to that hospital with this condition had complete dislocations and were treated by open surgical method. Sixteen operations were performed at Wadsworth Hospital on the acromioclavicular joint during the past ten years. The choice of the surgical procedure was as follows: seven patients had acromioclavicular and coracoclavicular wire ties, and in two instances the wires broke and had to be removed. Two had ligamentopexies. Four had acromioclavicular Kirschner, or threaded wires, or a Steinman pin. Three patients had excision of the outer end of the clavicle. One of these patients erroneously had 2 inches of the outer end of the clavicle removed and the stump of the clavicle presented itself subcutaneously. It is necessary, therefore, to limit the length of the clavicle to be excised to ¾ inch or not more than 1 inch and to repair the attachments of the deltoid and trapezius muscles so that the distal end of the clavicle will be contained in its proper place. If these simple measures were taken in performing the operation, the cosmetic and functional results of excisional surgery were generally excellent. This procedure was the simplest and the most widely used for neglected cases. The other procedures were used on fresh injuries and the end results consisted of improvement but not complete anatomical restoration of the joint.

2A

2B

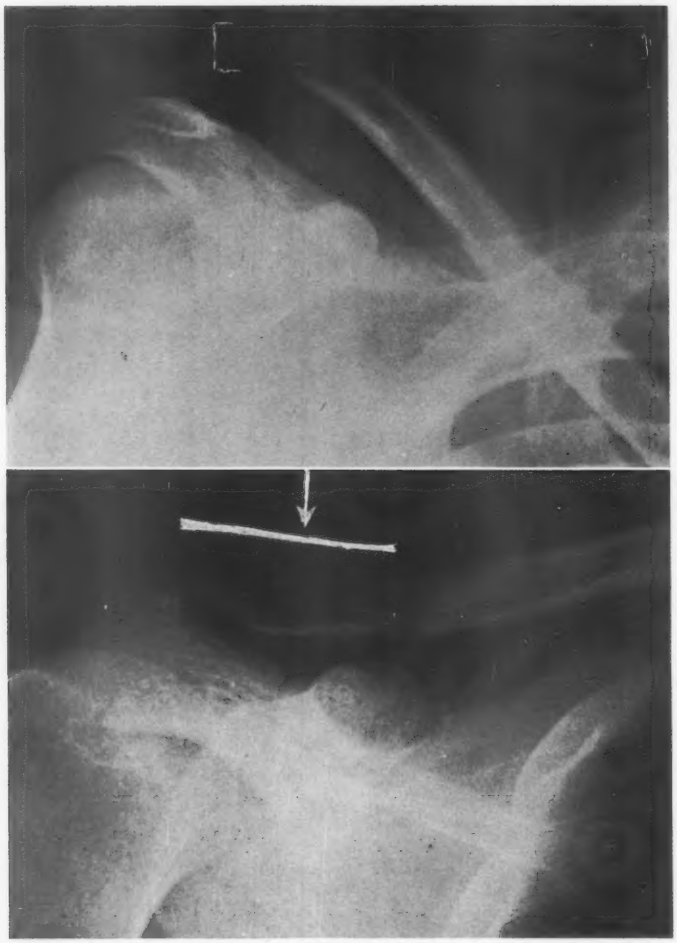

FIG. 2. A, roentgenogram (retouched) showing complete dislocation of the acromioclavicular joint in a twenty-four year old man. B, roentgenogram of the shoulder immobilized inside the splint shown in A, demonstrating the reduction of the dislocation. The clavicle is depressed below the acromion to produce a desirable state of overcorrection. The horizontal white line indicates the area of the elastic strap and the arrow indicates downward direction of the pressure on the outer end of the clavicle in the splint shown in Figure 1.

For most of the operations or modifications of operations on the acromioclavicular joint, less than 100 cases have been reported in the literature, and many writers fail to describe the long term end results of their use. There are, however, several hundred cases reported with satisfactory results following excision of the outer end of the clavicle. It would seem, therefore, on the basis of practicality at least, that currently this is the procedure that is the operation of choice, but it should not be recommended for routine use on fresh injuries.

Late Reactions and Complications. An interesting characteristic of the coracoclavicular ligament was its tendency to heterotopic bone formation, three to six weeks after injury. Both conoid and trapezoid ligaments showed this reaction. It has incorrectly been termed as calcification [*35*]. Actually, it is ossification which has been described in specimens removed

with the outer end of the clavicle, and examined both histologically and radiologically [2]. Soule [36] described seventeen cases and regarded it as an inevitable sequel to complete dislocations. Ossification was not prevented but actually even intensified by metal implants used for internal fixation of the coracoid process to the clavicle. It appears to be much less extensive and sometimes hardly noticeable in radiographs of patients treated by closed methods. DeSousa and Veiga [35] assumed that early motion of the shoulder aggravated this pathological process. Fortunately, the deposits of the new bone rarely result in a synostosis of the scapula and the clavicle. It may, however, produce a painful pseudarthrosis. Congenital malformations or anomalies have been discovered in routine chest roentgenograms that included the shoulder; this was non-symptomatic and had the structure of a vestigeal but true coracoclavicular joint.

A valuable contribution was recently made by DePalma [37], who made "decade studies" to investigate the process of aging of the acromioclavicular joint. He observed that fibrillation and erosion may develop in the articular cartilage as early as the third decade. Some persons actually showed gross osteoarthrosis, presumably due to the extraordinary degree and unrelenting nature of the movements of this part of the skeleton. These observations are particularly pertinent to the problem of the acromioclavicular dislocation because it is inevitable that changes of attrition and degenerative (post-traumatic) arthritis should develop following transarticular syndesmopexy, wiring, or screw fixation of this joint. These complications also occurred in patients treated with good results by closed methods, but with a lesser degree of involvement and no appreciable pain. This is strong evidence in favor of a policy of first, closed conservative treatment for fresh injuries and second, excision of the outer end of the clavicle to improve the cosmetic effect in unsuccessful or neglected cases.

Disability Evaluation. Complete dislocations of the acromioclavicular joint are rarely, if ever, disabling. When untreated or when treatment has been unsuccessful, nature plays one of her many old tricks. The patient may or may not feel that he was improperly treated, yet he is surprised that he has no loss of function. This leads some surgeons to adopt the policy of "masterful neglect" and then to decide that it is futile or unnecessary to do any more than prescribe an arm sling for a patient with an acromioclavicular injury. I observed one patient who played professional football and led his league in throwing completed forward passes with shoulders deformed by old bilateral complete dislocations of the acromioclavicular joint. Several cases have been cited of fellow physicians who refused treatment and boasted of no disability whatever from this deformity. These stories, however, should not be accepted unquestioningly and no policy of treatment can be based upon them. The fact is that it is true that complete dislocations with no contact between the clavicle and the acromion eventually become painless, but it is not a normal shoulder and cannot withstand sustained heavy lifting except for a short period. The troublesome cases are those with subluxating joints, in which the clavicle pops in and out of the joint, with folds or tears in the meniscus, and reactive or traumatic arthritis. These patients require and can be benefited by excision of the outer end of the clavicle with repair of the ligaments, muscle origins, and the attachments that hold the bone end in place.

Policy Regarding Participants in Organized Competitive Sports. The athlete with an acromioclavicular dislocation incurred in competitive games poses a special problem. The young athlete, in contrast to the industrial worker, tends to conceal his disability. He prefers to play rather than be subjected to treatment that will disqualify him from competition for six weeks. A practical solution to this problem is a conference consisting of the team physician, the student, the coach and the trainer. At this time, all four conferees should view the x-ray films, choice of methods of treatment, and our present knowledge of the end-results of acromioclavicular injuries. Unless all are willing to devote six weeks of the playing season to complete and uninterrupted immobilization, it is better to advise palliative measures such as protective strapping. Excision of the outer end of the clavicle can be offered at a later time, if the condition should become or remain symptomatic, and if the patient should insist on cosmetic treatment. It is not unwise to ask all interested persons in the case to enter into a written agreement on the course of management in some institutions where the physician is required to accept more responsibility than it is reasonable for him to assume.

SUMMARY

Dislocation of the acromioclavicular joint, being associated with relatively little disability, should be treated first by conservative methods employing a degree of immobilization that is in proportion to the degree of damage to the ligaments. Splints for this injury differ from other splints in that they perform a dual function: reduction and immobilization. The ideal splint for the disjointed acromioclavicular area has not yet been designed; it should depress the clavicle at the same time that it elevates the acromion process and the scapula. Although arduous to make and inconvenient for the patient, several acromioclavicular splints have been proved to be of value and worthy of wide use. To begin treatment with an extensive surgical dissection of the joint, to implant internal fixation, to encase the patient in a large cast to protect the internal fixation, to observe the inevitable breaking of fascial transplants, wires, or screws, and then to perform another operation to remove the metal, to leave a large scar on the shoulder, all for a condition that is largely a cosmetic problem is ovbiously irrational treatment. It is tantamount to shooting a dove with an elephant hunter's rifle, and it is the antithesis of sound practice of surgery. I have observed fifty-nine cases in men (none in women) during the fifteen-year period from 1943 to 1958, and have found surgical treatment necessary only in complicated or neglected cases. For such patients, usually individuals complaining of "an annoying deformity" or pain from the clavicle habitually popping in and out of the joint, it is advisable to excise the outer end of the clavicle and repair the origins of the deltoid and trapezius muscles so as to hold the end of the clavicle down in its proper anatomical compartment.

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Athletic Injuries to the Elbow, Forearm, Wrist and Hand

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ALTHOUGH competitive sports produce more major injuries to the lower extremity, a sufficient number of injuries to the upper extremity do occur to make a thorough review of their recognition and management worthwhile. Furthermore, since most of these injuries involve one of the major joints, such as the elbow or the wrist, inadequate treatment will often lead to permanent disability.

A number of factors are present which determine the type of injury sustained. Such factors are: the type of game (e.g., football, baseball, wrestling), experience and conditioning of the players, the type of forces applied to the extremity and the age of the player. Since the vast majority of college athletes are beyond the age of epiphyseal closure, it is obvious that epiphyseal injuries are rarely seen in the college group, whereas, they are common in the junior high school and high school group. Baseball produces frequent injuries to the fingers and thumb, while football and wrestling produce more injuries to the elbow and wrist.

FIG. 1. Simple posterior dislocation of the left elbow without fracture. Lateral view.

Management of athletic injuries on the Orthopaedic Surgery Service at The University of Michigan Hospital includes experience with injuries sustained in professional, intercollegiate, university intramural, high school, junior high school and "sand-lot" games. Players from every recognized collegiate or scholastic sport have been treated and the program outlined herein is based on this cumulative experience. These injuries will be presented according to their location.

INJURIES OF THE ELBOW

Dislocation of the elbow is one of the most common injuries to the upper extremity and has been encountered most often in injuries sustained in football. Other sports responsible for dislocations of the elbow have been wrestling, hockey, baseball and gymnastics. The diagnosis of dislocation of the elbow is usually not difficult. The mechanism is often a twisting or hyperextension injury. The player experiences immediate pain and loss of motion.

Examination will reveal lack of mobility of the elbow and deformity. Careful palpation of the bony prominences will disclose derangement of their normal relationships. Most dislocations of the elbow will fall into two groups. The first group includes the relatively simple posterior dislocation with minor ligamentous damage. The olecranon process is found thrust posteriorly along with the radial head. The radial head will be absent from its normal location just distal to the lateral epicondyle of the humerus. There is little or no lateral or medial displacement. (Fig. 1.) The radial and ulnar collateral ligaments are relatively intact and

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FIG. 2. A and B, football injury with posteromedial dislocation of the elbow. The dislocation was reduced on the playing field. Roentgenograms show the massive swelling secondary to hemorrhage. C, D and E, two months after injury. Calcification is present over the medial and lateral humeral epicondyles and in the olecranon fossa. The range of motion is normal except for a 20 degree loss of extension.

reduction is accompanied by a palpable and sometimes audible snap. Reduction may be accomplished with simple analgesia such as the intravenous administration of Demerol® although general anesthesia may be necessary.

The finding of relatively intact collateral ligaments is confirmed by the relative stability of the elbow noted after reduction. In such a dislocation, splinting is carried out only as long as pain and swelling are present; active range of motion exercises are begun early, often during the first week after injury. Between exercise periods, a posterior splint may be worn with the elbow at a right angle. After three weeks, the splint may be discontinued.

Prior to epiphyseal closure, the medial humeral epicondyle is weakly attached to the humeral shaft and is frequently avulsed when the elbow is dislocated. All degrees of displacement of the medial humeral epicondylar epiphysis may occur. The most marked displacement occurs in posterolateral dislocation of the elbow in which the medial humeral epicondyle may be widely separated from its bed and drawn laterally into the elbow joint.

A second group of dislocations of the elbow are those with associated medial or lateral displacement. These injuries are more severe and are associated with complete rupture of the collateral ligaments of the elbow. Massive swelling and hemorrhage are invariably found. (Fig. 2.) Dislocations of this type with the attendant loss of collateral ligamentous continuity are quite unstable. Reduction is char-

3A 3B 3C 3D

FIG. 3. A, posterolateral dislocation of the elbow. B, after reduction. Small avulsion fractures of the medial and lateral humeral epicondyles are visible. C, three months after injury. A small area of myositis ossificans is present near the coronoid process of the ulna. D, three months after injury. The avulsion fragments are barely visible.

4A 4B 4C

FIG. 4. A and B, posterolateral dislocation of the elbow. C, after reduction. A comminuted fracture of the lateral humeral condyle is visible.

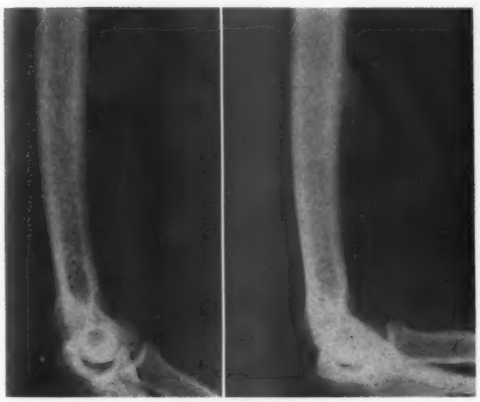
acterized by a tendency for the parts to move easily together and to redisplace with similar ease. Although this type of dislocation of the elbow must be splinted adequately to prevent redislocation and to allow healing of the torn collateral ligaments, early active motion is very important to restore range of motion. Usually, active motion is begun after three weeks of immobilization in a cast. Simple flexion, extension, pronation and supination movements can be begun under supervision. Between exercise periods, the elbow may be supported by a posterior splint. After the fourth week, splinting may be gradually discontinued.

Posterior dislocation of the elbow may be associated with a fracture involving the radial head, capitulum, or the coronoid process of the ulna. Medial or lateral dislocation may be associated with fracture of either the medial or lateral epicondyle of the humerus. (Figs, 3 and 4.) Very small fragments may be ignored while larger ones may need to be excised. Fragments of these structures may be included in the joint with reduction and should be removed if such an inclusion should occur. (Fig. 5.)

Myositis ossificans is a common complication of dislocation of the elbow and is most often found in the region of the insertion of the brachialis muscle into the coronoid portion of the ulna. (Fig. 3C.) Myositis ossificans may

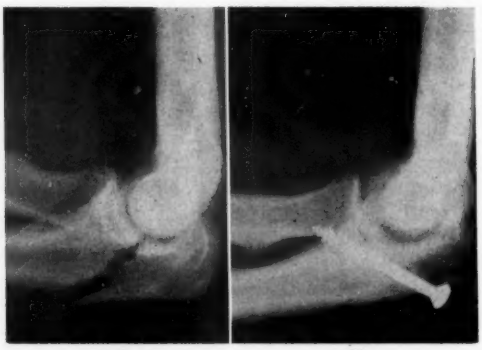
5A 5B 5C 5D

FIG. 5. A, fracture dislocation of the elbow in a fifteen year old boy. The medial humeral epicondylar epiphysis has been avulsed. B and C, following closed reduction. The medial humeral epicondylar epiphysis is included in the elbow joint. D, after open reduction and internal fixation of the medial humeral epicondyle. The ulnar nerve was transplanted anteriorly.



6A 6B

FIG. 6. A, myositis ossificans in the brachialis muscle. B, nine months later. The myositis ossificans has matured.



7A 7B

FIG. 7. A, fracture of the olecranon of the ulna involving the elbow joint. B, following open reduction and internal fixation of the olecranon.

occur in other areas about the elbow, for example, in the region of the medial and lateral epicondyles. (Figs. 2C, 2D and 6.)

Myositis ossificans occurs in the region of the elbow more commonly than about any other joint and may be seen following injury to or operative intervention in the elbow. Murray [1] has cautioned against poorly timed operations on the elbow as an exciting factor in the production of calcification. He described the time sequence in the reaction of soft tissue about an injured joint. He believed that open operative procedures should be performed within the first few hours; otherwise, operation should be postponed until all evidence of a pathologic condition of the soft parts has disappeared. The waiting period is usually two to three months or longer. Operation carried out after the reaction of the soft parts has reached its peak will increase the tendency to calcification and ossification.

Direct trauma to the elbow may produce a fracture of the olecranon process. The triceps muscle exerts a deforming force on this fracture with separation of the fragments. Open reduction with internal fixation is the preferred method of management of the displaced olecranon fracture. (Fig. 7.) Firm fixation of the fracture allows very early active motion of the elbow and avoids the necessity of immobilizing

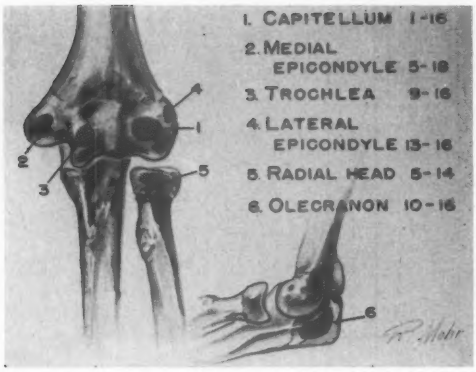


FIG. 8. Growth centers about the elbow. The approximate age of appearance of the centers and their fusion to the humeral shaft is given.

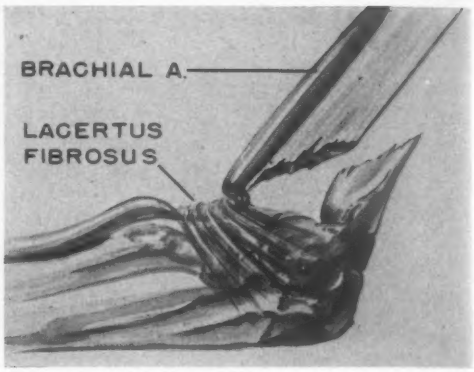


FIG. 9. Supracondylar fracture of the humerus with posterior displacement of the distal fragment.

the elbow in extension. The head of the radius is frequently fractured when impact forces are transmitted from the hand and forearm to the elbow. Relatively undisplaced stellate fractures of the radial head are treated by splinting of the elbow at a right angle. Active exercise is instituted as soon as pain subsides. Comminuted and displaced fractures of the radial head are treated by excision.

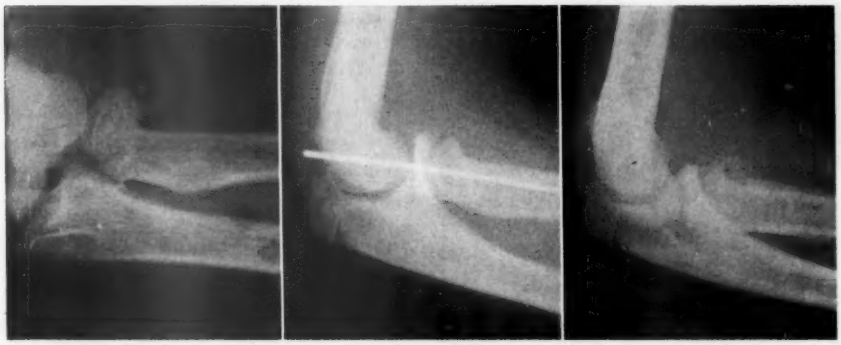
With the introduction of organized competitive sports into the junior high school program, more and more epiphyseal injuries can be anticipated. Injuries of the elbow in junior high school football must be evaluated with respect to the development of the ossification centers of the distal part of the humerus and the proximal part of the ulna and radius. The distal end of the humerus ossifies in four centers. The centers for the capitulum and the trochlea coalesce into a single mass of bone at ten to twelve years. However, the ossification centers for the lateral and medial epicondyles remain separated from the humeral shaft until just prior to the age of epiphyseal closure. (Fig. 8.) Fractures of the capitulum with lateral rotation and displacement of the capitulum are common below the age of twelve. Avulsion of the medial epicondyle may occur at any age up to the time of epiphyseal closure. Careful roentgenographic evaluation of these injuries is facilitated by having x-ray films of both elbows.

Prior to epiphyseal closure, hyperextension of the elbow most often produces a supracondylar or dicondylar fracture of the distal part of the humerus with posterior displacement of the distal fragment. Fractures of this type are usually associated with severe swelling and the threat of vascular embarrassment is always present. (Fig. 9.) The use of overhead skeletal traction with a Kirschner wire in the proximal end of the ulna and with the forearm suspended in a sling has enabled us to avoid the vascular complications of the supracondylar fracture. Traction may be utilized for a short period until swelling subsides and the arm can be placed in a splint, or the traction may be continued until callus appears. Three weeks is the usual period of traction. Manipulation of these fractures is seldom necessary in that the traction tends to reduce the fracture. Perfect functional results have consistently followed the use of this type of traction.

The epiphysis of the proximal end of the radius appears at about four years of age and unites with the shaft at fifteen years. Displacement of this epiphysis may occur up to the time of epiphyseal closure. Angular displacement can usually be reduced by closed manipulation, utilizing direct pressure on the displaced radial head. Severe displacement may require operative replacement. (Fig. 10.) The proximal radial epiphysis should not be excised.

EPICONDYLITIS, TENDONITIS AND BURSITIS

We have frequently encountered acute tendonitis and bursitis involving the radiohumeral bursa and the common tendon of origin of the forearm extensor muscles from the lateral humeral epicondyle (epicondylitis humeri). In



10A 10B 10C

FIG. 10. A, severe displacement of the proximal radial epiphysis in a thirteen year old boy. The fragment was very unstable. Closed reduction was unsatisfactory. B, open reduction was carried out. The unstable fragment was fixed with a Kirschner wire. C, after removal of the Kirschner wire. Callus is present around the radial neck.

FIG. 11. A and B, anterior Monteggia injury (fracture of proximal part of the ulna and anterior dislocation of radial head) in an eight year old boy. C and D, two months after reduction. The ulna is healed and the radial head is in normal alignment with the capitulum.

acute cases, severe point tenderness and swelling are noted directly over the epicondyle or over the radial head. Sports responsible for such irritations of the elbow are tennis, golf, fishing (fly casting), track (javelin throwing) and baseball (pitching). Repetitive movements of the elbow especially in pronation and supination seem to be a factor in producing epicondylitis humeri and radiohumeral bursitis. In addition to the localized pain and tenderness, radiating or referred pain may be felt in the forearm and hand. Pain may also be referred in a retrograde manner into the arm. Symptoms are increased by dorsiflexion of the wrist.

Conservative measures which have been useful have included rest with splinting and the application of moist heat to the elbow. The local injection of hydrocortisone has produced gratifying results in many cases.

Occasionally, deposits of calcium are seen in

12A 12B 12C

FIG. 12. A, complete transverse fracture of both radius and ulna in a fifteen year old boy. The fragments of the radius were rotated and locked so that a satisfactory reduction of the radius could not be obtained. B, open reduction and internal fixation of the radius were performed. C, nine months after injury both bones are healed and the plate has been removed.

FIG. 13. *Top*, distal radial epiphyseal separation in a fifteen year old boy. *Bottom*, three months after reduction. Closure of the epiphysis has taken place.

the soft tissue overlying the lateral humeral epicondyle. These are usually found in recurrent or chronic epicondylitis. Operative removal of the calcium has occasionally been necessary. In resistant cases of epicondylitis, operative stripping of the common extensor tendon has provided relief.

THE FOREARM

Fractures of the bones of the forearm are relatively common in athletic injuries. Proximally, the ulna is often fractured along with anterior dislocation of the radial head in the so-called Monteggia injury. (Fig. 11.) Hyperextension is the mechanism of this injury. Closed manipulative reduction followed by immobilization in plaster is the method of management. In the adult patient, closed reduction of the radial head may be incomplete because of interposition of the annular ligament. Open reduction with reconstruction of the annular ligament and intramedullary fixation of the ulna should be performed. Operative reduction should be carried out early. If operation is delayed, the danger of excessive ossification is present. The reverse or posterior Monteggia injury is very uncommon.

Direct blows to the ulnar aspect of the forearm will produce occasional isolated fractures of the ulna. These are usually undisplaced and respond well to immobilization in plaster. Greenstick fractures of both bones of the forearm are common in the junior high school and high school groups. Closed reduction and immobilization in plaster for eight to ten weeks will suffice.

Displaced fractures of both bones of the forearm prior to the age of epiphyseal closure should be treated with closed manipulation and cast. When a displaced fracture of the radius and ulna occurs in an athlete beyond the age of epiphyseal closure, open reduction and internal fixation with plate or intramedullary pin will give the best results. Even in the young, athletic patient, fractures of the shaft of the radius and ulna are slow to heal and the surgeon must be prepared to prolong immobilization in plaster until union is sound. (Fig. 12.) Delayed union of both bones of the forearm should be treated by early bone grafting.

Injuries to the distal end of the forearm may produce damage to the distal radial epiphysis. Such injuries are uncommon after twelve years of age. Hyperextension commonly causes dorsal displacement of the distal radial epiphysis. Frequently, a small triangular fragment of bone from the dorsal radial cortex remains attached to the epiphysis. (Figs. 13 and 14.) Closed

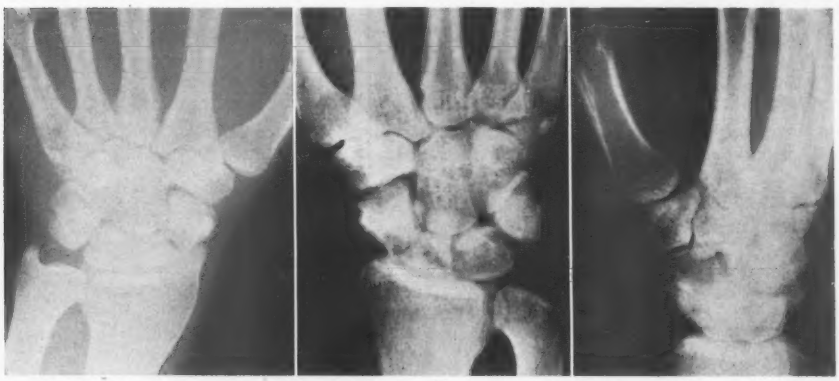
FIG. 14. A and B, volar displacement of the distal radial epiphysis. C, following reduction, the wrist is held dorsiflexed in plaster. D, six weeks after injury the radius is healed.

FIG. 15. A, a university football player sustained a blow to the outstretched thumb. There is a comminuted fracture of the greater multangular bone. B, two months after injury. The greater multangular bone is healing. C, one year after injury. Early traumatic arthritis is present in the carpometacarpal joint.

reduction is not difficult unless complete displacement of the epiphysis with overriding is present. A disturbance of growth following distal radial epiphyseal separation is rare unless there has been direct damage to the epiphysis causing a fracture through the epiphysis or crushing of the epiphyseal plate. (Fig. 13.) Special care on the part of the surgeon to obtain reduction of the displaced epiphysis by a single manipulation is essential. Repeated

16A 16B

FIG. 16. A, fracture through the waist of the carpal scaphoid bone. B, five months after injury, the fracture is healed.



17A 17B 17C

FIG. 17. A, non-union of carpal scaphoid. Arthritic changes are present between the scaphoid and the radial styloid. B and C, after excision of the styloid process of the radius and autogenous graft of the scaphoid. The graft was taken from the distal radius.

manipulations are apt to cause damage to the epiphyseal plate and subsequent abnormality in growth.

CARPAL INJURIES

The surgeon attending athletes must be prepared to manage a great variety of carpal injuries. Although fracture of the carpal scaphoid bone is the most common carpal fracture, we have seen isolated fractures of each of the carpal bones. Failure to recognize such fractures and to immobilize the wrist may lead to non-union and traumatic arthritis. (Fig. 15.)

It must be emphasized that a fracture line may not be visible immediately after injury in any of the usual routine four to six x-ray views of the wrist. These injuries should not be dismissed as "sprains," but should be immobilized as fractures of the carpal scaphoid for two weeks. Another set of roentgenograms then, with the carpus out of plaster, will very often reveal a fracture line. Sprain of the wrist is therefore a diagnosis of exclusion.

In young athletic males, carpal scaphoid fractures will usually heal if immobilized for an adequate period. (Fig. 16.) Non-union is usually the result of an unrecognized fracture or an

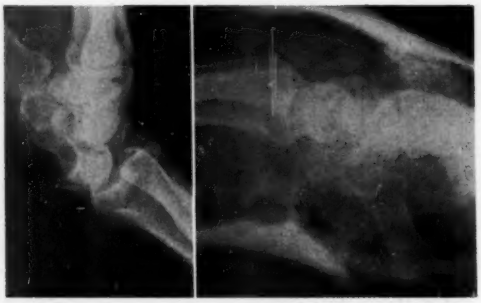
18A 18B

FIG. 18. A, non-union of carpal scaphoid twenty-one months after injury. There is localized intercarpal arthritis. B, ten months after excision of the carpal scaphoid.

inadequate period of immobilization. Ununited carpal scaphoid fractures commonly exhibit associated traumatic arthritis involving the radiocarpal joint or the adjacent intercarpal joints. When non-union is present in a carpal scaphoid fracture, two basic operative approaches are available to the surgeon. Excision of the styloid process of the radius along with autogenous grafting of the navicular has been used. (Fig. 17.) The graft may be taken from the distal radius, the tibia or the ilium. Excision of the carpal scaphoid has given consistently good results in this clinic. (Fig. 18.) Excellent functional results in outstanding athletes have been obtained. In cases of severe traumatic arthritis of the carpus, fusion of the wrist must be considered.

Carpal dislocations with or without fracture will occasionally be seen in athletic injuries of the wrist. Severe hyperextension may produce anterior dislocation of the carpal lunate. (Fig. 19.) Reduction by closed technic should be attempted, but, if not successful, should be followed by prompt open reduction. Repeated manipulative attempts at closed reduction of the anteriorly dislocated lunate may lead to damage to the median nerve. An unreduced dislocation of the carpal lunate may lead to interference with the median nerve and the causalgia syndrome. Following reduction of the lunate, a carpal tunnel syndrome may develop secondary to swelling.

Severe hyperextension and radial deviation of the carpus causes the navicular to impinge



19A 19B

FIG. 19. A, anterior dislocation of the carpal lunate bone. B, after reduction in plaster, the lunate is restored to its normal position in the wrist.

upon the radial styloid. Trans-scaphoid perilunar fracture dislocation of the carpus often follows this injury. The scaphoid is fractured through its waist. The proximal scaphoid fragment and the lunate remain in the normal relationship with the radius while the distal scaphoid fragment and the remainder of the carpal bones are displaced as a unit in a dorsoradial direction. Occasionally, the radial styloid is also fractured in this injury. (Fig. 20.)

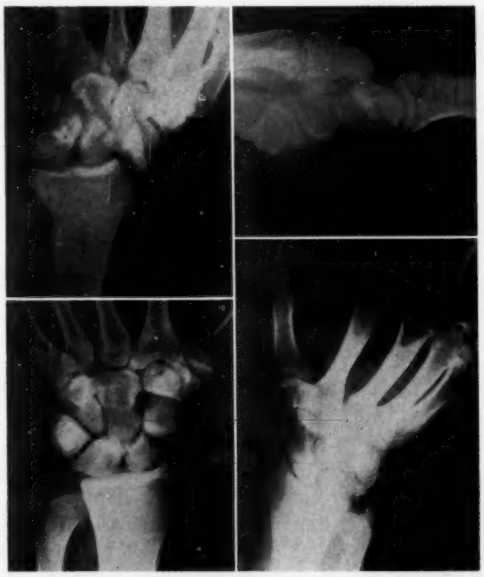


FIG. 20. *Top*, trans-scaphoid perilunar fracture dislocation of the wrist. The radial and ulnar styloid processes are also fractured. *Bottom left*, immediately after reduction. *Bottom right*, six months after injury the fractures are healed.

FIG. 21. *Top*, Bennett's fracture of base of first metacarpal. *Middle*, reduction maintained in plaster cast. *Bottom*, four weeks after injury, the fracture is healed.

Closed reduction and immobilization in a short arm plaster including the thumb should be carried out until union of the scaphoid fracture is sound. Aseptic necrosis of the lunate following dislocation may occur. Excision of the necrotic bone is indicated. If aseptic necrosis of the proximal fragment of a fractured scaphoid occurs, bone grafting will assist revascularization. If the proximal fragment represents less than one-third of the navicular, and aseptic necrosis is present, it should be excised.

INJURIES TO THE HAND

Metacarpal Injuries. Bennett's fracture of the base of the first metacarpal is quite common in athletic injuries. A blow on the tip of the outstretched thumb tends to force the first metacarpal proximally. The unique shape of the base of the first metacarpal with its saddle-like configuration makes it prone to fracture. The fracture separates the projecting medial lip of the metacarpal base and allows proximal subluxation of the first metacarpal on the greater multangular bone. Reduction of this fracture dislocation can be accomplished by traction and abduction of the thumb. (Fig. 21.) Skeletal traction utilizing a Kirschner wire through the first phalanx is often necessary to maintain a good reduction. After four weeks, traction may be discontinued. Occasionally operative reduction is advisable. Fixation with screw or Kirschner wire may be used.

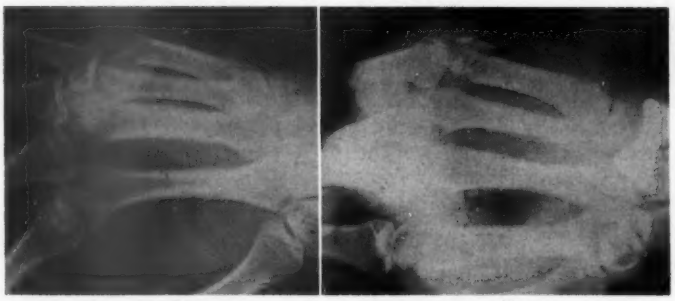
Metacarpal fractures can be grouped according to the configuration of the fracture. Transverse fractures of the shaft and fractures at the base of metacarpals two through five are reduced and immobilized for four weeks. Immobilization is accomplished with a short arm cast incorporating a curved, metallic, padded splint under the involved finger. (Fig. 22.) The finger is placed in a flexed position of function. If a metacarpal fracture is oblique and tends to override or angulate, skeletal traction is utilized with a Kirschner wire through the middle or distal phalanx. After three weeks, traction may be discontinued and the hand immobilized in a cast with the involved finger supported on a metallic splint in a flexed position.

Fractures through the metacarpal neck with depression of the head of the metacarpal are often troublesome to reduce. Acute flexion of the finger with the metacarpophalangeal joint flexed 90 degrees allows the surgeon to control the head of the metacarpal. Upward pressure on the metacarpal head through the proximal phalanx will lift the dropped metacarpal head. (Fig. 23.) Caution must be used to avoid necrosis of the skin over the proximal interphalangeal joint, however.

Digital Injuries. Phalangeal fractures are managed by immobilizing the digit in flexion

22A 22B

FIG. 22. A and B, oblique fractures of the third and fourth metacarpals with minimal overriding.



23A 23B

FIG. 23. A, fracture of the neck of the fifth metacarpal with depression of the head. B, after reduction and application of a splint. The dropped head has been corrected. Slight lateral displacement persists.

on a padded, malleable metal splint for two to three weeks.*

Dislocations of the metacarpophalangeal joints and interphalangeal joints are extremely common in athletic injuries. In simple posterior dislocations, the collateral ligaments are relatively intact, and after reduction splinting in flexion for seven to ten days will suffice. However, if lateral displacement of the joint has taken place, one of the collateral ligaments must have been disrupted and careful treatment must be carried out. (Fig. 24.)

* Reduction of fractures of proximal phalanges and unsupported metacarpals can be maintained and in addition a fair range of active motion obtained by the use of a simple skeletal traction hook inserted through the dorsal cortex of the middle phalanx. (QUIGLEY, T. B. and URIST, M. R. Interphalangeal joints. *Am. J. Surg.*, 73: 175, 1947.)

Accurate reduction and retention of reduction for at least three weeks are indicated. If any residual lateral instability is noted, open repair of the collateral ligament is in order. Neglected lateral instability will lead to a disabling, unstable joint. (Fig. 25.)

Injuries of the hand, other than fractures or dislocations, are very common. We have encountered isolated ruptures of flexor tendons in baseball, basketball and football players. Prompt repair utilizing the Bunnell pull-out wire technic is ideally suited for repair of these tendons. Ruptured long extensor tendons may be repaired with the Bunnell figure eight steel wire technic.

The so-called "baseball finger" represents one of the most common digital injuries. Avulsion of the extensor mechanism from the

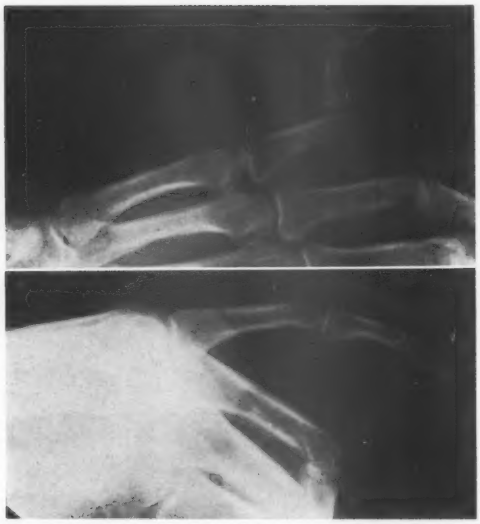


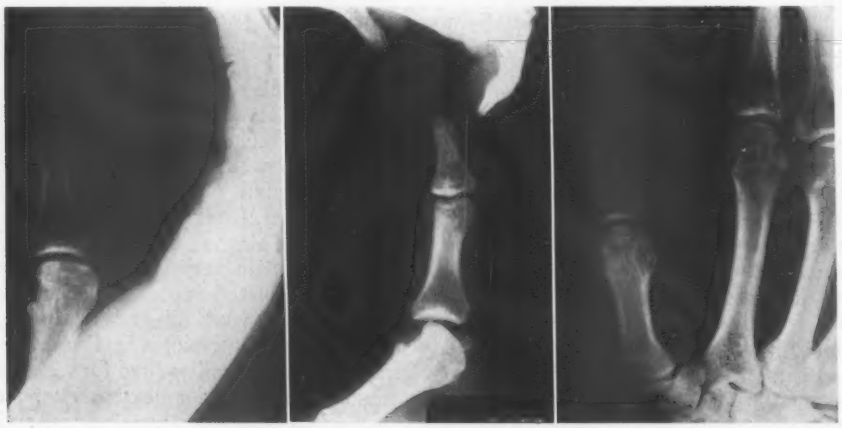
FIG. 24. *Top*, compound dislocation of the proximal interphalangeal joint of the little finger. *Bottom*, three weeks post injury. The collateral ligaments are healed.

distal phalanx causes a flexion deformity of the distal phalanx. Frequently, a triangular fragment of bone is avulsed from the dorsal tip of the base of the distal phalanx. Although the closed splinting technic with the proximal interphalangeal joint in flexion and the distal interphalangeal joint in extension has given good results in many instances, operative repair has produced uniformly good results and avoids the hazard of necrosis of the skin. If a small fragment of bone has been avulsed from the distal phalanx, the splinting technic will succeed if satisfactory reduction of the avulsed fragment can be obtained. In the absence of an avulsion fracture, opposition of the torn tendon fragments is uncertain and open repair will ensure a good result. If the closed technic is elected, splinting is carried out for six weeks. Lateral x-ray films will confirm retention of reduction of the avulsed fragment. Operative repair of the tendon allows the time of splinting to be shortened to three weeks.

Rupture of the extensor tendon to a finger at its insertion into the base of the middle phalanx allows the so-called "boutonniere" deformity with flexion of the proximal interphalangeal joint and extension of the metacarpal phalangeal and distal interphalangeal joints. Repair by the figure eight stainless steel wire technic is followed by splinting for three to four weeks.

COMPLICATIONS

The surgeon treating athletic injuries must be constantly aware of the major complications which may result from such injuries. Open wounds must be thoroughly débrided and irrigated prior to closure. The value of delayed



25A 25B 25C

FIG. 25. A and B, old neglected dislocation of the metacarpophalangeal joint of the thumb. Marked lateral instability is present which interferes with pinch and grasp functions. C, after reconstruction of the collateral ligaments, the thumb was stable for a short period. Recurrence of instability made arthrodesis of this joint necessary.

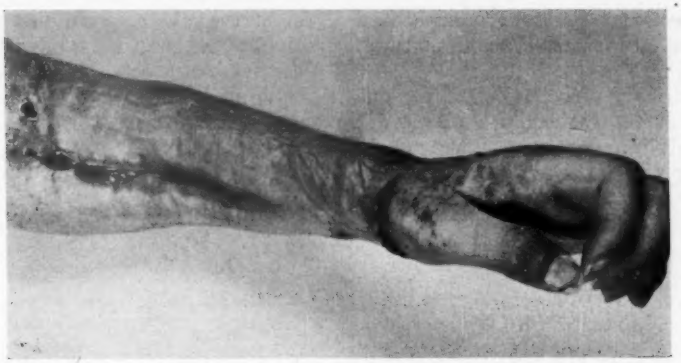


FIG. 26. Severe Volkmann's ischemia of forearm and hand following fracture of the forearm bones sustained in football. Damage was so severe, amputation was necessary.

primary closure in badly contaminated wounds or in wounds with extensive contusion of tissue should not be overlooked. Vascular and neural complications of fractures and dislocations must be constantly kept in mind. We have seen an extremely severe Volkmann's ischemia of the forearm following a closed fracture of radius and ulna sustained in a high school football game. (Fig. 26.) Compression neuropathy of the median nerve has been seen in injuries of both the elbow and wrist. Delayed ulnar neuritis has been seen in an old valgus deformity of the elbow. (Fig. 27.)

Injuries to the epiphyses have the potentiality of giving rise to future disturbances of growth. In general, epiphyseal separations in which the epiphyseal plate is neither fractured nor crushed are not followed by the arrest of growth. However, fractures which traverse the epiphyseal plate or which cause a crushing injury to the epiphyseal plate will often produce the arrest of growth. Young athletes with epiphyseal injuries must be followed up closely with repeated careful measurements and x-ray examination to determine whether or not growth has been disturbed. This is of particular importance in injuries of the wrist and elbow. Premature closure of the distal radial epiphysis will lead to an unpleasant deformity of the wrist with radial deviation of the hand and prominence of the distal ulna. Premature asymmetrical closure of the distal humeral epiphysis leads to a valgus or varus deformity of the elbow depending on the lateral or medial location of the humeral injury.

Traumatic arthritis may follow any intra-articular injury. Osteochondritis dissecans of the elbow usually involves the capitulum of the humerus. Traumatic arthritis is very prone to develop in the wrist in the presence of an ununited fracture of the carpal scaphoid.

In all athletic injuries, early active exercises will minimize loss of joint motion. Active exercises for muscle strengthening and range of motion should be started at the earliest possible moment. Even after a severe dislocation of the elbow, active exercise is begun after three weeks' immobilization. Passive stretching is never allowed. In the presence of myositis

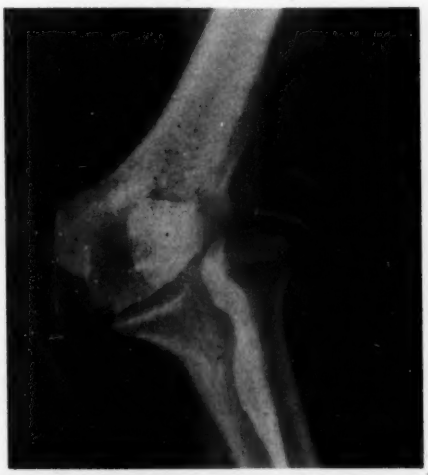


FIG. 27. Cubitus valgus secondary to an old ununited fracture of the lateral condyle of the humerus. Neuritis of the ulnar nerve was treated by anterior transplantation of the nerve.

ossificans, active exercise is encouraged and the bony mass grows smaller and matures. (Fig. 6.)

Athletic injuries may be neglected for one of several reasons. Occasionally a player will conceal an injury in order to avoid being taken from the lineup. The attending surgeon should emphasize to coaches, trainers and players the necessity of a careful and thorough evaluation of all injuries. Only by prompt and effective treatment can the surgeon restore the injured part to a good functional status.

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Athletic Injuries to the Abdomen and Thorax

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INJURIES to the abdominal and thoracic walls are common in athletics. Serious injury to the abdominal and thoracic viscera can also occur. Fortunately, these are rare. Soreness may persist for some time even after a relatively minor injury. On the other hand, the apparent rapid recovery of a young, healthy athlete does not exclude internal injury. The realization that the spleen, liver, small bowel and intrathoracic organs can be injured, coupled with careful and repeated examinations of the injured athlete will improve the safety of sports. The presence of shock, pallor, continued pain or any respiratory difficulty warrants the patient's hospitalization for careful observation.

INCIDENCE

Abdominal and thoracic injuries probably account for less than one-fifth of all athletic injuries. It is difficult to determine the true incidence. Little has been published on athletic injuries alone [7]. From the reports of abdominal injuries it can be determined that less than 10 per cent are due to sports. This may be due to the fact that trauma applied slowly is less likely to cause visceral damage than sharp, sudden blows [4]. Welch and Giddings [8] state that 40 per cent of non-penetrating abdominal injuries fall into a category labeled "miscellaneous." This group includes falls and blows resulting from work as well as sports. Cottrell [1] states that 8 per cent of injuries to the abdomen are due to kicks and blows and 11 per cent to falls but no mention is made of sports. Other reports also fail to delineate athletic injuries from other injuries relative to both the abdomen and thorax [3,5].

The frequency of athletic injuries to the abdomen and chest has been further investigated in two ways. First, the injuries occurring in the varsity football program at Ohio State University over a five-year period have been reviewed. Second, the admissions to the University Hospital for more serious abdominal and chest injuries during a ten-year period have been reviewed for injuries occurring in athletics.

It might be expected that abdominal injuries would be seen frequently during varsity football. This has not been the case. Between 1951 and 1955 there were 1,032 football injuries. Fifty-two involved the abdomen. (Table I.) There were twenty-six contusions of the lateral abdominal wall above the iliac crest, twelve muscular strains in the groin, four muscle strains, and ten more serious injuries. This latter group included six contusions of the kidney, three severe abdominal wall contusions, and one ruptured spleen. Four of the athletes with renal injury had hematuria. The player with the ruptured spleen had the only abdominal injury requiring laparotomy in the past thirty years of varsity football.

Thoracic injuries were even less common. (Table II.) There were twenty-eight injuries to

TABLE I
ABDOMINAL INJURIES IN VARSITY FOOTBALL*

Type of Injury	No.
Contusion of abdominal wall above iliac crest	26
Muscle strain in groin	12
Strain in other areas	4
Kidney contusion	6
Contusion other areas	3
Ruptured spleen	1
Total	52

* From 1,032 injuries incurred from 1951 to 1955 (two patients were hospitalized).

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TABLE II
CHEST INJURIES IN VARSITY FOOTBALL*
1951–1955

Type of Injury	No.
Contusion of sternum	8
Costocartilaginous separation	8
Contusion lower ribs	10
Fractured ribs	2
Total	28

* None hospitalized.

the chest wall. These included ten players with contusion of the lower costal margin, eight with sternal contusions, eight with costochondral cartilaginous separations, and two with fractured ribs. There were no associated intrathoracic injuries.

Athletic injuries occurred 21 times in a series of 200 hospital admissions for abdominal trauma during a ten-year period. (Table III.) Therefore, sports were responsible for more than 10 per cent of the patients admitted with blunt abdominal trauma. Football was by far the most common sport involved. In this series of twenty-one admissions, seventeen injuries occurred in football, two in skating, one in sledding and the other in soccer. The abdominal organ most frequently injured was the kidney. Renal injury occurred in twelve of the twenty-one cases. Injury to the abdominal wall and spleen was noted four times each. Injury to the pancreas was responsible for one admission. The relative incidence of injury to intra-abdominal organs in sports is similar to that from other causes. Solid organs are more often injured than hollow viscera.

Athletic injuries to the chest in patients requiring hospital admission have been a rare finding in this series. Only three such patients have been admitted in the past ten years. Two of these had fractured ribs with pneumothorax and in the other a pneumothorax developed from a penetrating injury of the chest wall during fencing practice. No patients with serious chest injuries due to athletics have been seen.

ABDOMINAL INJURIES

One of the most common injuries in sports is the "solar plexus" injury. The athlete complains that he has had his "wind knocked out."

TABLE III
SPORTS INJURIES TO THE ABDOMEN*

Type of Injury	No.
Kidney contusion	12
Abdominal wall contusion	4
Ruptured spleen	4
Traumatic pancreatitis	1
Total	21

* From 200 hospital admissions for abdominal trauma, 1948 to 1957.

These injuries are not usually recorded because of their transient nature. No treatment is necessary since the condition responds to a few moments of rest and reassurance. It is important to realize that the injury is of extremely short duration. If rapid recovery does not occur, if signs of shock are present, or if local pain and tenderness persist, visceral injury should be suspected.

Muscle Contusions Above the Iliac Crest. This is a common injury to the lateral abdominal wall. It occurs in football and other sports from direct trauma in which the muscle and fascia above the iliac crest is bruised. Swelling and tenderness occur immediately. Occasionally a hematoma will develop. The differential diagnosis between hematoma and visceral injury may be difficult. In this series, fracture of the ileum has not been seen.

Application of cold and adhesive strapping are effective in relieving the pain. If induration is present shortly after injury, the indurated area can be injected with hyaluronidase dissolved in 15 to 20 cc. of 0.5 per cent procaine. This not only produces effective pain relief but also shortens the period of swelling and disability. Local applications of heat and massage should then be used daily until active motion is normal. Even after active motion has returned to normal, local tenderness usually persists and recurrent blows are extremely painful. In football, after such an injury, a curved fiber or fiberglass protection is usually applied over the iliac crest and the lateral abdominal wall for two to three weeks.

Muscle Strain in the Inguinal Region. The most common muscle strain in the abdominal wall is in the inguinal region. It involves not only the muscles of the anterior abdominal wall but also the iliopsoas muscle. Twelve of these

were seen in this series. Because of the location of the pain, an inguinal hernia must be ruled out. Presence of pain on elevation of the knee and flexion of the hip indicates this muscle strain. The injury responds rapidly to treatment with heat and rest.

Visceral Injury. Renal injury is the most common injury to the abdomen and the easiest to diagnose. Contusion or laceration occurs but severe shattering of renal parenchyma has not been noted. In about seven of ten such injuries hematuria will be found on microscopic examination. When hematuria is found, the diagnosis of either renal or bladder injury should be confirmed by intravenous pyelography and/or cystographic studies. The management of renal injury is usually non-operative [5]. Catheters should be used only when definitely indicated.

Splenic rupture should be suspected in any athletic injury involving the lower left rib cage or upper part of the abdomen. Although about a third of these injuries will be associated with fractured ribs, evidence of contusion or fracture may be totally lacking. The diagnosis is dependent upon clinical findings. Evidence of impending shock, such as sweating, paleness, and a rapid pulse extending beyond the few minutes after cessation of exercise, are indications for the patient's hospitalization. Pain and tenderness may be diffuse or limited to the upper left portion of the abdomen. Occasionally there is pain in the left shoulder due to irritation of the diaphragm. This can often be made to occur by placing the patient in the Trendelenberg position. An increase in the white blood count may suggest the need for laparotomy [9], however, neither this finding nor an anemia are constant enough to be reliable. A miniature paracentesis, using a long spinal needle, will more often than not yield blood. A negative tap should not be interpreted as evidence against splenic rupture. When sufficient doubt exists, based on clinical findings, laparotomy is safer than prolonged observation. At the time of laparotomy a thorough abdominal exploration is necessary to rule out possible concomitant rupture of the liver, bladder, duodenum, small intestine or colon which should be repaired at the time of splenectomy.

Other serious intra-abdominal injuries are rare in athletics. Traumatic pancreatitis with the formation of a pseudocyst has been noted once in our series. This occurred during football, and after conservative treatment a pseudocyst developed. The diagnosis can be made if suspected and if blood amylase is obtained. Treatment should be vigorous with adequate replacement of blood volume using either whole blood, plasma, or serum albumin [2]. Injuries to the intestinal tract have not been encountered in our series, but one laceration of the jejunum requiring primary surgical closure has been noted at another hospital.

THORACIC INJURIES

Costochondral Separation. This painful lesion was seen in only eight patients in five years of varsity football, and is also seen in other sports. These injuries occur from a fall or blow to the anterior and lateral chest wall. Severe pleuritic pain begins immediately after injury and becomes more severe in the next few hours. This pain lasts from twelve to forty-eight hours. It can be relieved by local injection of procaine into the intercostal nerve involved or by adhesive strapping of the chest. After the acute pain has subsided, sharp pain on motion may last as long as six weeks. Some benefit can be obtained in prolonged cases by infiltrating the local area with 10 to 15 cc. of 0.5 per cent procaine to which 1 cc. of hydrocortisone has been added. A chest roentgenogram should be taken although in costochondral separation no pulmonary or pleural findings have been observed.

Contusion of the Lower Ribs. This is a form of costochondral separation of the lower four ribs. The area of injury is along the anterior costal margin. Pain and tenderness are not as severe, and seldom last more than one week. Some patients with these contusions may require adhesive strapping for twenty-four to forty-eight hours. All patients with contusions of the lower ribs should be carefully followed for signs of injury to the abdominal viscera.

Fractured Ribs. Only two players have been found to have fractured ribs. Both of these were linear fractures without displacement. Neither of these players showed evidence of damage to the lung or pleura on follow-up roentgenograms. All subjects with fractures, however, should be watched for signs of injury to the lung and pleura, and should have chest roentgenograms taken. The treatment of fractured ribs is similar to that of costochondral separation.

Intrathoracic Injury. Athletic injuries to the chest in patients requiring hospital admis-

sions have been a rare finding in our series. Only three patients with such injuries have required admission during the past ten years. Two of these patients had fractured ribs with pneumothorax. In the other a pneumothorax developed from a penetrating injury. This patient, and one of the two with a pneumothorax due to a fractured rib, were discharged forty-eight hours after admission and required no specific treatment. The third patient was treated by closed thoracotomy for forty-eight hours and discharged on the fourth hospital day. No patients with serious chest injuries due to athletics have been seen.

Three complications of injury to the chest wall which may occur include subcutaneous emphysema, pneumothorax and hemothorax. The former two are determined by palpation and auscultation of the chest. The latter is suspected if there is an increase in the pulse rate associated with pallor and sweating. Chest roentgenograms should be obtained in all patients with chest injuries. Only tension pneumothorax becomes a real emergency. This must be treated immediately by needle aspiration or closed tube thoracostomy using a sterile catheter or polyethylene tube. Subcutaneous emphysema alone or pneumothorax of less than 20 per cent unassociated with hemothorax requires ouly rest and observation. More severe pneumothorax or hemothorax requires needle aspiration. Some surgeons prefer tube thoracostomy to needle aspiration. Open thoracotomy is indicated for severe bleeding or failure of aspiration.

SUMMARY

The practical surgical management of patients with abdominal and thoracic injuries due to sports will be the same as that for patients with similar injuries from other trauma. It is not unusual to see serious abdominal injury following an automobile accident. The same awareness that serious abdominal and thoracic injury can occur in sports is important. Although abdominal injury due to athletics is less common, the same problems in examination and management of the patient arise. Minor injuries to the abdominal and thoracic walls may be treated by rest, immobilization by strapping, the application of heat and massage, or the local injection of anesthetic. When intra-abdominal and intrathoracic injury are suspected the athlete should be hospitalized for careful observation. When visceral injury is found to occur, its treatment does not differ from similar injuries due to other causes.

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Athletic Injuries of the Pelvis, Hip and Thigh

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To be discussed herein are the more common injuries in the region of the pelvis, hip and thigh. Of all sports football is most productive of athletic injuries, similar injuries occur in wrestling, lacrosse, track, basketball and baseball, but much less frequently.

In achieving a diagnosis, at least an immediate working diagnosis, the history of the injury is of prime importance. The important facts are: the mechanism of the occurrence, the initial site of pain, when it was first noted, its severity and the incapacity imposed, the development and spread of the pain, the character of immediate and later swelling and disability. A history of previous similar injuries should be sought.

Physical examination of the injured part must be complete. Inspection at rest and under gentle use, if possible, followed by palpation is performed. Then, if the injury permits, one puts the part under gentle stress by maneuvers designed to test the various structures.

Adequate indicated x-ray examination, not fluoroscopy, permits one to be confident that all possible means of initial investigation have been exhausted. Roentgenograms are a means only of confirming or denying a tentative diagnosis.

The initial diagnosis may require revision days or even weeks later. New developments and manifestations, response to treatment, and residual disability will indicate this. In the great majority of instances it is wise, initially, to "over-investigate and under-treat."

Early treatment, tempered by the diagnosis, for most injuries consists of rest, compression and the application of cold. These limit further damage, confine the effects of the damage, relieve pain, and diminish the initial response of the body to the injury. One must constantly remember that "pain means strain" and that strain, stress and irritation of an injury aggravate it and interfere with healing. This will serve as a guide in the treatment and indicate when to return the injured part to full use.

The application of cold is of benefit during the first twenty-four hours. Occasionally it is used longer. When the initial reaction to injury begins to subside, gentle comfortable heat is substituted. Again, too intense or prolonged heat will cause discomfort and should be moderated. Rest and compression are continued.

Rest does not mean absolute immobility. It is relative. It may include the entire body, the limb or the part. It may consist of various devices or simply modified use. Again, pain is the most reliable guide. In like manner, compression and other modalities of treatment can be adjudged probably beneficial if one considers a similar principle, "If it does good, it is good."

To these all-inclusive and basic principles are added specific measures as indicated by the injury.

INJURIES OF THE PELVIS

The most common cause of disability in the region of the pelvis and hips is a contusion or bruise of the rim of the pelvis. Although provided with adequate protection, carelessly applied or deranged pads may permit a direct blow to the iliac crest. Most commonly the injury is sustained while blocking, being tackled, or by being thrown forcibly to the ground. As the abdominal and hip muscles are attached here and are used in all activities, the contused area obtains little or no rest until pain is disabling. Like most muscle and muscle-attachment strains, the greatest pain comes on several hours after activity has lessened.

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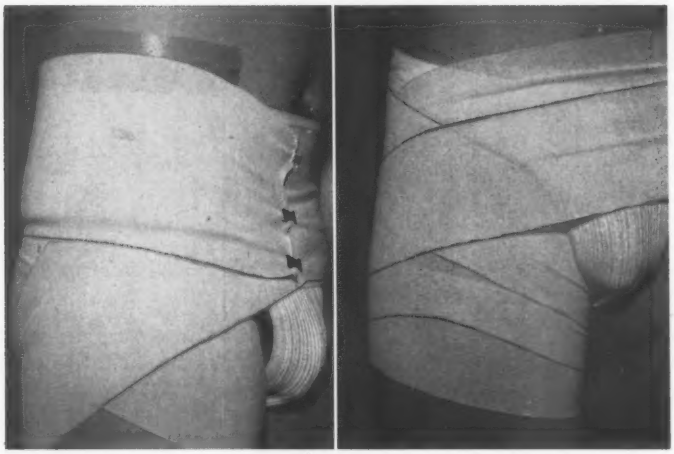

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FIG. 1. Compression bandage for contusion or strain of muscle attachments to pelvic rim.

FIG. 2. Compression spica bandage for strained groin.

Pain and tenderness are localized to the rim of the ilium. When the abdominal muscles are tensed by bending to the opposite side, pain is reproduced. If disability is severe, prolonged more than two days, or is present in the adolescent, roentgenograms should be obtained to eliminate avulsion of the rim apophysis or fracture.

Initial treatment consists of ice, compression and rest. Compression is obtained by an encircling elastic bandage compressing a thick soft sponge. (Fig. 1.) This also produces some degree of local rest. Cold is usually eliminated after the first few hours, and after eighteen to twenty-four hours gentle comfortable heat for thirty-minute periods is substituted. Disability, except in the more severe injuries, lasts no longer than several days. Return to competition or contact activities is permitted when pain and tenderness disappear.

Less commonly, violent muscular effort, a blow upon a tense muscle, or over-stretching of attached muscles may result in a strain at the attachment of the abdominal muscles to the iliac crest, inguinal ligament or pubis. In like manner, the anterior muscles of the thigh may be strained, and pain and tenderness found along the inguinal ligament, on the pubis or the anterior iliac crest. The possibility of hernia and bony injury must be eliminated by careful local examination and by x-ray examination if indicated. The treatment and prognosis are along the same lines as those previously discussed. (Fig. 2.)

Strain of the ischiopubic attachments of the adductor muscles of the hip deep in the crotch, and of the hamstring muscles deep under the buttocks are also common and usually occur during preseason or early practice sessions. They occur during "wind-sprints," blocking practice, and while kicking. Trackmen incur them commonly while jumping, practicing "starts" and hurdling.

These "hamstring pulls" are caused either by sudden, strong and incoordinate use or overextension of the untrained and unconditioned muscle. The muscle itself is not yet ready for the job it is called upon to do. The diagnosis is made by careful local examination. Treatment follows the previously described time-honored and result-justified regime. A compression spica bandage (Fig. 2) will give comfort and support.

With severe symptoms, structural alteration and local swelling one must suspect avulsion fracture of the bone at the site of muscle attachment. A properly posed x-ray investigation will confirm the diagnosis of an avulsed portion of the iliac crest, anterior superior or inferior spine of the ilium, or ischial tuberosity. In the growing high school athlete, whose growth lines are still present, the entire apophysis of the iliac crest or ischial tuberosity may be avulsed.

Again, treatment is generally along the lines already described. There is rarely an indication for replacement of the avulsed bone by open reduction and only occasionally is a cast needed to maintain a relaxed position of the involved muscle. A separated attachment of part of the muscle does not displace over 1 inch because of the remaining attachments; if the entire muscle attachment is torn loose, the muscle loses its normal tone and pain reflexly keeps it relaxed while producing spasm in synergists to maintain position. Generally, bed rest for one to three weeks is all that need be employed. Limited ambulation with crutch or cane may then be allowed. Mechanical support by bandaging and strapping, and physiotherapy with gradual return to function are used concurrently. The avulsed bone heals by strong scar tissue or by bony union. There is usually no permanent disability. The time required for complete healing is normally four to six weeks.

The extremely rare fractures of the pelvis other than the avulsion type are potentially more serious. They are caused by extreme violence. Bloody urine indicates injury to the bladder, kidney or urine passageway. Hospitalization and individualized care are indicated.

INJURIES OF THE HIP

Injuries to the hip joint are rare in college athletes. In younger athletes, they are uncommon but potentially very disabling unless an early definitive diagnosis is achieved.

Simple strain of the ligaments of the hip joint is diagnosed in the adolescent by exclusion of more serious disease. It manifests itself by pain in the groin, occasionally in the buttock or lateral aspect of the hip. The pain may also be designated as appearing in the inner side of the lower part of the thigh or knee. It is intensified by motion of the hip alone and by weight bearing. The limp is usually a flexion-antalgic type in which the body is bent forward, little motion is present in the affected hip, and weight is borne but briefly on the limb.

The hip is limited in motion by muscle spasm, most commonly elicited by abduction and/or internal rotation. Generally tenderness may be elicited only anteriorly. Roentgenograms indicate no abnormalities. Rest, perhaps reinforced by traction, gives considerable relief. If improvement is prompt and repeated anteroposterior and lateral x-ray films of the femoral head and neck indicate no abnormalities one can then make this diagnosis.

FIG. 3. Acute slipped femoral epiphysis. (From: RENO, J. H. Slipped upper femoral epiphysis. *St. Luke's Hosp. Bull.*, May, 1954.)

Rest, limited and graduated painless use, and perhaps mild heat are all the treatment required. Rest is effectively achieved by bed rest, or the use of traction or crutches, as indicated by the degree of pain and muscle spasm and by the reliability of the patient to follow instructions.

In adolescents, between ten and fifteen years of age, displacement of the epiphysis of the femoral head may occur. (Fig. 3.) This may be the result of minimal trauma, or a symptomless displacement may become symptomatic as the result of accelerated activity. The symptoms and signs are generally the same as for simple strain. Symptoms at times are referred to the medial part of the thigh or knee. If the disturbance of the epiphyseal-metaphyseal relationship is sufficient, a fixed external rotation deformity of the limb may be manifest. Properly posed x-ray films may show no abnormality other than slight rarefaction of the hip region generally and perhaps some rarefaction and loss of trabecular detail in the metaphysis of the femoral neck. If the displacement is greater than minimal, it will be disclosed on these films.

Treatment by an orthopedist is indicated and he will use those methods he has found most successful. Once the epiphyseal line has disappeared through surgery or conservative treatment, full activity may be resumed. Residual disability is usually slight once the muscles have become rehabilitated.

FIG. 4. Legg-Calvé-Perthes disease.

FIG. 5. Avulsion of the lesser trochanter.

In the Little League class, and these immature children are even engaging in organized football, epiphysitis of the femoral head may be brought on or brought to light by trauma or simply increased use. The symptoms and signs are those of a sprained hip. The diagnosis is made by lack of response to short rest and by x-ray findings. The minimal roentgenographic findings are: slight rarefaction of that area of the hip, slight spasm of the hip as manifested by a smaller obturator foramen as seen on the anteroposterior pelvic films, and rarefaction of the femoral head or neck along the epiphyseal line. In the more advanced stages of the disease the diagnosis is easier. The diagnosis must be remembered for these minimal findings for they lead to the diagnosis of Legg-Calvé-Perthes disease. (Fig. 4.) Treatment of this condition is complete rest for the hip and is best guided by the orthopedist.

Inflammation of the greater trochanteric bursa in athletes is usually the result of a direct blow. Occasionally the tendons of insertion of the abductor and extensor muscles are also contused and thus the disability is prolonged and accentuated by activity. Treatment consists of rest by use of crutches, local physiotherapy and infiltration of all the tender areas by procaine and/or Hydrocortone.®

Avulsion of the lesser trochanter is rare but has been observed. (Fig. 5.) As with most avulsions, displacement is generally less than 1 inch and hence does not require replacement. Treatment is the same as for other avulsion fractures.

Fracture of the femoral neck or intertrochanteric region of the femur is seldom seen. However, the exact diagnosis is made through the use of roentgenograms and treatment is the same as in adults.

INJURIES OF THE THIGH

Simple contusion of the anterior aspect of the thigh is one of the most common disabling injuries suffered by football players. Loose, poorly positioned and otherwise inadequate thigh pads are responsible. The injury consists of bruising of all soft tissue between skin and bone. Bleeding occurs within the muscle and this irritating blood spreads throughout the flesh like water throughout a sponge. The muscle fibers are broken, much like a tough steak is broken up by pounding with a hammer. The subcutaneous fat is liberated from its confines like the pulp of an orange when it is crushed. The blood, bruised fat and muscle are sources of chemical irritation. The force of the injury to these tissues plus the continued use which often takes place for a short time immediately after the episode are major factors in producing the disability.

Several hours after injury, swelling from edema and bleeding may increase the size of the thigh alarmingly. It becomes tense, painful, and the skin itself exquisitely tender. Mild pressure on the muscle produces marked pain. Early gentle palpation may rarely detect a dent in the subcutaneous fat or even the underlying muscle at the point of contact. This may

occasionally be found after healing and represents death of the tissues as a direct result of the blow.

It requires four to six weeks for the injury and its accompanying irritants to heal. This time may be lengthened by continued use or unwise treatment and advice. Again, basic principles find their worth. Rest, compression and cold are all that is required for the first day or two. This injury, if severe, is the one injury for which a brave, hardy, stoic football player will follow professional advice and actually use the crutches provided. Occasionally, bed rest for several days is required.

After the first few days, rest, compression and a comfortable amount of heat are used. Activity with or without weight bearing is dependent upon the amount of pain produced. This is *the* reliable guide. Absence of pain means absence of strain, stress or irritation. Healing will be aided. No other treatment is needed until the muscle recovers to the point of decreased size, more normal softness, and painless use in moving the knee. Then and only then are progressive resistance exercises for the quadriceps muscles commenced. When 25 to 35 pounds for ten excursions can be raised, crutches for rest, balance, security and protection of the knee are no longer needed. When the average athlete of high school age or older can raise about 50 pounds he can usually run. However, a lifting strength of 75 to 100 pounds for ten excursions is usually needed before "digging-in," sudden starts and stops, "cutting," and agility will be possible to a sufficient degree to permit wrestling, basketball or football.

This is the "charley-horse." Its cause lies in inadequate protection. Its recovery is prolonged. Often complete flexibility of the muscle never returns, even after years have passed, because of the scarring within the muscle, where the flesh was crushed. Usually this is not sufficient to interfere with adequate motion of the knee; it is the final 20 degrees of flexion that are lost.

When the injury extends down to bone and crushes the muscle fibers attached thereto, formation of bone results in the associated blood clot as nature attempts to heal the junction of muscle and bone. The bone is overproduced, for the hematoma is a continuous medium, and a large mass of bone may result. This will be manifested by non-softening of the muscle after four weeks of good care and by x-ray films. This bone will resorb if left alone. It will obviously resorb more slowly than soft scar, or clotted or liquid blood. To operate and remove it surgically is difficult and well nigh impossible for it is distributed through the muscle as liquid cement would be distributed through a sponge before hardening. Intelligent adherence to Nature's plan and masterful noninterference is the practical means of treatment. Continued painless use is all that is required. As the months roll by, ability improves, and if one takes roentgenograms at long intervals, the size of the bony mass will lessen.

Diathermy, x-ray therapy, ultra-sound and other methods of treatment with machines are used. Massage is used, often intelligently and consequently with comfort. No one has yet conclusively demonstrated any advantage of treatment with machines over the basic principles already described. Psychologically, there may seem to be value in these other modalities. However this is subjective, benefiting the sufferer because of the additional tender loving care and the therapist because he is elevated in the sufferer's eyes in so providing attention. This is harmful, not necessarily physically but psychologically and religiously. Both sufferer and therapist forget thereby that Nature, God or something other than themselves is effecting recovery and that their duty is not to interfere. Time is required to rebuild tissue. Patience and trust must be painfully learned. Learning this will benefit both therapist and sufferer in the manner that competitive sports are supposed to benefit mankind.

This is true in all injuries and it behooves those of us who have contact with these adolescents of high school and college age to teach them these basic truths.

Muscle "pulls" occur in the thigh less frequently than in the pelvic or buttock regions. The more common strain of a muscle attachment is that of the origin of the short (femoral) head of the biceps. The injury usually is the result of awkward or of excessive kicking, occasionally of sudden strenuous starts from the crouched position. In kicking, the long head of the biceps (attached to the ischium) may not get the excessive strain because of pelvic rocking. Pain, tenderness and tenseness are found in the midline of the middle third of the posterior aspect of the thigh. Disability is minimal, discomfort mild, and recovery comes about in

several days as the result of rest and the application of mild heat.

A careless block or other cause of a blow to the outer aspect of the thigh is the usual cause of pain and tenderness along the course of the iliotibial band, running from the greater trochanter to the lateral aspect of the knee. Trochanteric bursitis, mentioned before, is a less frequent source of these manifestations. Neither are common. The common thigh guard does not cover this area. Treatment is symptomatic, using rest and the application of mild heat. If symptoms and disability warrant, almost complete rest, by using crutches, is indicated to relieve the structures of the stress of weight bearing.

Fracture of the femur is rare. It requires marked force. This reporter has never seen it in adolescent or older football players. It has occurred in children under high school age.

Sports Injuries to the Genitourinary Tract

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IN reviewing the injuries sustained during the past ten years by students participating in various college athletics in nine of our leading universities with active sports programs, I was amazed to find a very small, almost insignificant incidence of trauma to either the kidneys, urinary bladder or external genitalia. Except for the kidney, there was no record of any major or significant injury to the genitourinary organs.

External Genitalia. The external genitalia require some form of protection in all contact sports. In the majority, the ordinary elastic supporter or jockey strap is all that is required, but baseball catchers use a plastic or metal cup worn inside the elastic supporter. (Fig. 1.) This extra protection is also usually worn by hockey players, lacrosse goal tenders, and some football centers, as well as by anyone who has previously had some external genital injury.

In the reports from the universities that graciously furnished me with their records, one case of contusion of the testis occurring during a softball game was reported. Others reported mild contusions of the testis with no complications.

One interesting fact came to light, namely, that those who have once had a contusion of the testis are very likely to use the additional protection of a plastic or metal cup in subsequent events. This observation is significant; it helps to substantiate the rule that when a boy has only one normal and normally functioning testis he should be barred from participation in any subsequent major athletic activity. The game is not worth the risk of injury to the only remaining normal and normally functioning member of paired organs. This rule is strictly adhered to in most colleges, and should be adopted universally. This will exclude those who have an undescended testis, those who have had atrophy as a result of mumps orchitis, those who have had a torsion of one testis, and those who have undergone orchiectomy for any reason whatsoever. Boys with large hydroceles, spermatoceles or varicoceles of any consequence should have these surgically corrected before participating in contact sports as they would be very prone to injury. A boy with an undescended testis, especially if the testis is in the inguinal canal or at the external ring, and especially one with an ectopic testis, should be barred from contact athletics. One should also be on guard against allowing a boy with a highly mobile testis to participate in major athletic activity, as contraction of the cremaster may draw the testis up over the pubis and place it in the same jeopardy as an ectopic testis. It may even undergo torsion. Torsion is, however, very unlikely while an elastic supporter is worn.

If an injury does occur, it should be dealt with promptly. Contusion of the testis, which is the most common, should be treated by bed

FIG. 1. Elastic supporter or jockey strap worn to protect the external genitalia. The plastic or metal cup which is sometimes worn inside is also shown.

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rest, elevation of the scrotum, and an ice pack until all the swelling and tenderness has disappeared. I do not know from my own experience whether any of the new anti-inflammatory agents which reduce edema, hasten the absorption of blood and lymph, etc., will be of benefit, but they may be very well worth using.

A hematocele or a hematoma of the scrotum should be treated in the same way unless the scrotal hematoma is developing rapidly and progressively. Then, immediate surgery is indicated, as the torn blood vessel should be ligated.

If a torsion of the testis is immediately recognized it can occasionally be untwisted, but this is very rare. Immediate surgery is preferable. The diagnosis is best made by obtaining the history of an active, mobile testis. On examination, the diagnosis is established if: (1) the testis is found to be high in the scrotum, exquisitely tender, and very swollen, (2) the epididymis can not be felt in its normal posterior relation to the testis, (3) the vas deferens cannot be separated from the swollen, edematous, twisted cord, and most significant (4) if the scrotal skin is edematous and the scrotal contents are adherent to it.

The Penis. There is no record of any injury to the penis. It is almost impossible to injure the flaccid penis when it is held firmly against the body with an athletic support. The only time that an injury can occur is during an erection.

The Urinary Bladder. Like the penis, the urinary bladder is free from injury. The last thing a player does before going onto the field is to empty his bladder. The empty urinary bladder is like the empty bladder of a football; a collapsed, folded sac. The bladder only begins to assume its normal spherical shape when about 100 cc. of urine has accumulated within it. It does not begin to undergo its normal rhythmical contractions so that one can be aware that there is any urine within the bladder until about 150 cc. has accumulated. When the normal bladder first gives any indication of the necessity to urinate, it usually contains 300 to 350 cc., and at this time it is still below, and protected by, the pubis. Any blow or injury, therefore, to the lower abdomen can in no conceivable way injure the bladder before it is full, and usually not until it is overdistended. This is very graphically illustrated in Hugh Young's textbook on urology [3]. (Fig. 2.) If, therefore, an athlete empties his bladder just before going onto the field, the game will be over long before he has any desire to urinate. His bladder will, therefore, at all times be protected and hidden behind the bony pubic arch.

If at any time the symphysis pubis is separated by fracture of the bony pelvis, then the urethra is liable to be torn at the apex of the prostate. If this occurs then reapproximation of the separated ends of the urethra can readily be accomplished by doing a suprapubic cystotomy and approximating the torn ends by means of traction with a balloon catheter which has been introduced through the urethra into the bladder [4]. (Fig. 3.)

The Kidney. The kidney is by far the most common organ of the genitourinary system to receive some injury during athletic activities. This does not occur because renal injury is common (for it is remarkably rare) but because, by comparison, the external genitalia and the urinary bladder are rarely, if ever, injured. When one considers the anatomical location of the kidney and how magnificently it is protected by nature, it is surprising that a normal kidney in its normal position can ever be injured.

Normally the upper third of the right kidney and the upper half of the left kidney lie above the twelfth rib and are protected by the costal cage. Each kidney lies comfortably on the soft psoas muscle adjacent to the vertebral column. It is protected in front by the three abdominal muscles and the abdominal contents contained within the peritoneum, and posteriorly by three strong layers of abdominal muscles and fascia. Any tensing of the abdominal muscles protects the kidneys and absorbs any blow or shock. The only time, therefore, that one would expect a contusion, laceration, or rupture of the kidney is when the person is not on guard and receives a sudden and unexpected blow, as in an automobile accident or a fall from a building, etc. One would not expect an athlete with all his muscles tense and on guard to be able to sustain an injury of any significance to his kidney. Injuries received in accidents during skiing, bob sledding and similar activities should, of course, be classed in the same category as automobile accidents.

Up to the time that we began to study "march hematuria" during World War II, gross or microscopic hematuria following athletic activities was considered as being possibly due to contusion of the kidney, or, if the hema-

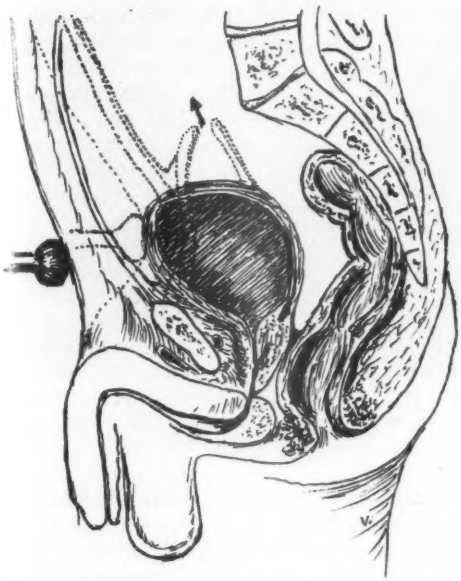

FIG. 2. Diagram showing the mechanics of a rupture to the full bladder from a blow on the anterior abdominal wall. (From: Young's Practice of Urology, vol. 2, p. 147. Philadelphia, 1926. W. B. Saunders Co.)

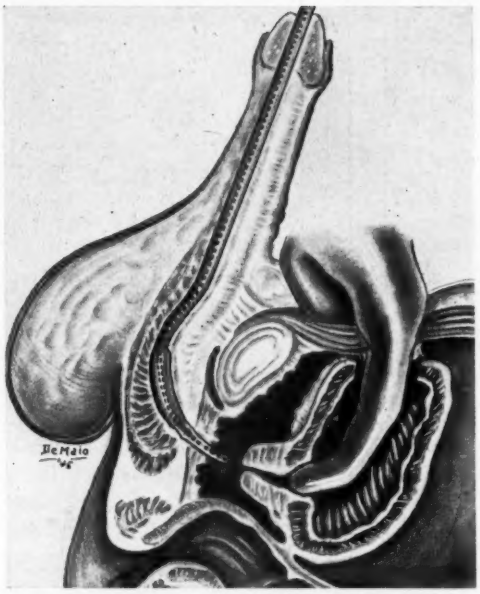

FIG. 3. Method of introducing a balloon catheter through the torn urethra into the bladder. (From: VERMOOTEN, V. Rupture of the urethra, a new diagnostic sign. *J. Urol.*, 56: 234, 1946.)

turia was gross or prolonged, as a possible laceration. Now the observations of Alyea and Parish [1] and others show that this hematuria is transient, that it occurs more commonly after track than football, and more commonly after swimming than boxing or wrestling. Therefore, unless we have more evidence of renal injury than hematuria, we cannot consider the diagnosis of contusion, laceration, etc. of the kidney as being established. There should be pain, psoas spasm, and evidence of blood loss. Actual proof of renal injury will have to be obtained by excretion urography or preferably retrograde pyelography. An injury of this type occurred in December, 1956 when a college football end was struck forcibly in the right flank. He experienced severe pain but kept on playing. After the game he had gross hematuria and was hospitalized. An excretion urogram (Fig. 4) showed normal and normally functioning kidneys. His pain persisted, as did his gross hematuria. At the end of seven days a mass was apparent in the region of the right kidney and an excretion urogram revealed hydronephrosis with stasis on the right side. (Fig. 5.) Surgical exploration revealed a large perirenal hematoma. When this was evacuated a laceration of the kidney was seen which was sutured. Convalescence was uneventful. This man is now playing professional football.

Athletes in some football teams wear hip pads with upward extensions designed to protect the kidneys from behind (Figs. 6A and B); others wear the regular curved kidney pads. One university uses its own design of hip pads which also protect the kidneys. In five years of top flight All-American college football, it is stated that there have been no injuries to the kidney except "two flare-ups in boys who have had previous trouble." Another university using the usual curved kidney pad in football has had no injuries to the kidney in the past ten years. A third university, whose primary athletic activity is football, reports "only one contusion of the kidney in the past seven years resulting from a football scrimmage." Yet in this institution, in which "approximately 4,700 engage in the rougher intramural athletics (touch football, basketball and softball) each year," the athletic director says, "rib pads offer adequate protection for the kidneys; ends and any backs who are apt to do the

FIG. 4. Excretion urogram made a few hours after injury to the kidney, during a football game, resulting in gross hematuria. Both kidneys appear to be normal and to function normally.

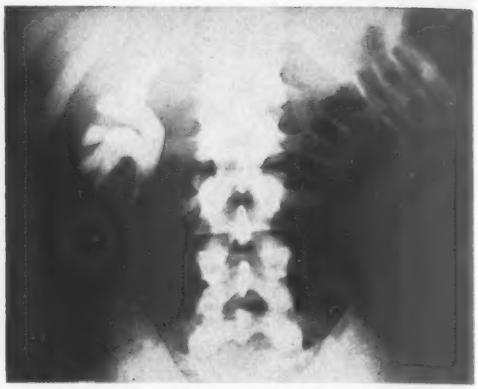

FIG. 5. Excretion urogram made a week later on the same patient as shown in Figure 4. Note the hydronephrosis on the right side due to perirenal hematoma.

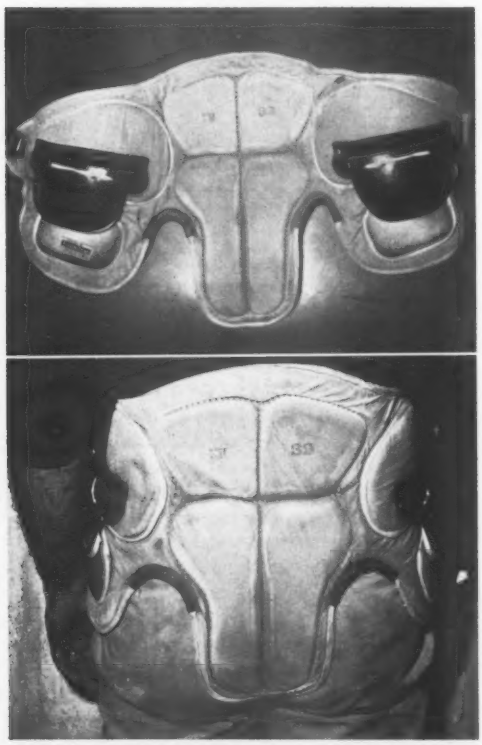

FIG. 6. *Top*, hip pads with upward extensions on both sides of the midline to protect the kidneys. *Bottom*, hip pads with the kidney protectors as worn by a football player.

blocking wear them." A fourth university in which accurate reports of injuries for the past twenty-six years have been kept finds "only four instances of kidney complications in athletics." Three were due to blows in the lumbar region. Two of these boys showed only transient hematuria. The third was a football player who had a rather extensive perirenal hemorrhage which required a blood transfusion but no surgery. The fourth received a "medical injury" to the kidney. "The 'scat back' who was probably the fastest runner in a football suit in the State during his three years of varsity play took no exercise whatever after his final game in November. The following May, at an intramural track meet, the manager for his fraternity entered him in the 100-yard dash requiring two heats, which he won, and in the 400-yard relay, the 220 and the 440. In the middle of the 440 he collapsed and fell to the track. He vomited once on the way to the shower and went to his room exhausted, but was unable to sleep. After an hour and a half he went to supper, but was unable to eat and returned to bed. At midnight he was awakened by acute paraspinal muscle pain on the right side; he voided without noticing his urine and came to the hospital where he was examined by a medical assistant resident. He was found to have marked muscle spasm in this area. No other findings were noted. A plain x-ray film of the abdomen was within normal limits. The pain subsided and he returned to his room only to be awakened from restless sleep by acute nausea and vomiting and the passage of dark red urine.

He returned to the hospital. Subsequent urination was scanty, and showed a positive result in a benzidine test. No red cells were noted; he was oliguric for forty-eight hours, then polyuric. His non-protein nitrogen rose to 78 but was back to normal after nine days. I have since learned of two similar instances which occurred many years ago."

Another university records two patients with injuries to the kidney who required nephrectomy during the past twenty years, and at least "one or two contusions each year that required hospitalization for two weeks." The interesting observation was made that each injured student was an end who was blocked with his arms extended above his head while reaching for the ball. In this position his trunk muscles could not protect his kidneys. Further, the injuries were frequently of the contrecoup variety. In football, ends and backs wearing kidney pads, rarely ever receive any injury to the kidney when being blocked from behind.

One other university also reported a ruptured kidney which necessitated nephrectomy. This injury occurred during an intramural game. Two contusions were also recorded during this university's ten-year period. In one an excretion urogram was "not remarkable" and in the other no radiographic examination was made. During the past ten years in which these records have been kept, this school which has an "athletics for all" policy put five hundred men into contact sport every day in the Fall.

Alyea and Parish [1], reviewing "renal response to exercise," report that as long ago as 1907 Collier reported the finding of albumen in the urine of athletes after severe exercise, and that in 1910 Barach reported the finding of albumen, red blood cells and casts in the urine of marathon runners and baseball players. Alyea and Parish [1] then studied the urinary findings before and after track, lacrosse, crew, football and swimming. They found that red blood cells were present in as high as 80 per cent following track, lacrosse and swimming, and only about 55 per cent following football and rowing. Although the hematuria was mostly only microscopic and transient, there were some instances in which the hematuria was gross but, nevertheless, transient. The authors feel that these episodes of transient hematuria are significant and suggest that they leave some permanent damage and scar. However, it will take a long period of time involving careful follow-up to determine whether or not there actually is any serious or significant damage to the kidneys as a result of this almost universal finding. It is particularly significant that the incidence of hematuria is far greater in track and swimming than in such violent contact sports as football.

In direct contrast to these observations, Kleiman [2] reports that hematuria developed after boxing in only 27 per cent of the boxers whom he examined, and the majority of these patients were boxers with congenital anomalies. Excretion urographic studies were performed in one hundred instances in which microscopic hematuria was observed. Among these there was "excessive renal mobility" on the right side in twenty-two patients, and on the left in ten patients. The upper calyx showed an "impaired contour" on the right side in forty-eight patients and on the left side in fifteen patients. As no excretion urograms were made prior to the boxing bouts, it is difficult to evaluate the significance of these findings especially as the hematuria, even when gross, was transient, as in Alyea and Parish's cases.

Kleiman [2] found that a fourth (twenty-six our of 100) of his patients with hematuria had "hydronephrosis," and another fourth had congenital anomalies. In 1933, while in South Africa, I saw a boxer in consultation because of gross hematuria and severe pain following each boxing bout. Radiographic examination revealed a horseshoe kidney. I divided the narrow isthmus and performed a right-sided nephropexy. Three months later he was boxing again. He had no more episodes of gross hematuria, but I presume that he must have had some microscopic hematuria.

Examining twenty retired middle-aged boxers who had fought hundreds of bouts, Kleiman found that the urinalysis was normal in all but one, and this one person had a pyelonephritis following the removal of a renal calculus. Two of these twenty men had "excessive renal mobility." As trauma usually heals, and healing means scarring, one would therefore expect that any renal injury would result in fixation of the kidney rather than increased mobility. Consequently one must assume that this incidental finding may have contributed to the hematuria but could not possibly have resulted from any renal injury.

Renal hematuria following boxing should therefore be classed with hematuria following all other forms of athletics. The amazing fact

from Kleiman's observations is that after boxing, hematuria is only half as frequent as after football, and only a third as frequent following track or swimming. Renal injury during boxing must therefore be considered an even less common experience than in other athletic activities.

These observations confirm my previous thesis that the kidney is a very well protected organ, especially in a person who is under tension and whose muscles are on guard. In the presence of congenital anomalies and hydronephroses, in which the vessels going to the kidneys are frequently abnormal, transient hematuria is apparently more common.

It therefore appears that renal injury as evidenced by microscopic or gross hematuria follows all forms of strenuous exercise; that it is less common in contact sports such as football and boxing than in other sports; and that in boxing when the body muscles, especially the abdominal muscles, are tense and on guard, the kidney is particularly well protected.

Therefore, the management of renal hematuria in athletics resolves itself. If the hematuria is gross or is associated with pain, urographic studies should be performed. If a hydronephrosis is present, or if there is any impairment of renal function in one or both kidneys, then further participation in any form of athletics should be stopped. A urologic consultant will best be able to determine the need for corrective surgery or otherwise.

Contusions and lacerations can be treated conservatively by bed rest for at least two weeks and by the forcing of fluids. A rupture of the kidney can usually be treated conservatively as the bleeding is into Gerota's fascia so that in a short while the pressure of the hematoma within the fascia stops the bleeding. A tear of one of the major renal vessels usually requires immediate surgery in the same way that a rupture of a hydronephrosis does. In most instances the diagnosis, and a good evaluation of the prognosis, can be made on excretion urography. Occasionally retrograde pyelograms may be necessary for diagnostic purposes. In no circumstances should an attempt at surgical treatment be undertaken until sufficient evidence and proof has been established that another kidney is present, and that it is adequate to maintain life.

SUMMARY

Injuries to the genitourinary tract in sports are rare. The kidney is more frequently involved than the bladder or genitalia. Hematuria is not at all uncommon. Careful observation and conservative management is all that is usually necessary. Surgical intervention becomes necessary on very rare occasions. Strangely enough, hematuria is less common in contact sports than in track, swimming and similar activities.

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Injuries to the Knee

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THERE are various types of pathologic conditions which can result from an injury to the knee. The knee is subject to the same stresses and strains and receives the same contusions as does any other joint. Indeed, it is more vulnerable than the other joints of the body. This is due not only to its exposed position which renders it liable to direct injury from blows applied or from falling, but also due to the anatomical characteristics which make it subject to tremendous leverage action in both lateral and rotatory stresses. In this article I will omit discussion of such extrinsic conditions as contusions, bursitis and Osgood-Schlatter disease. Neither will I discuss bony injuries such as fracture of the condyles and of the patella or acute and recurrent dislocations of the patella. These conditions, while vastly important, are beyond the scope of this article. I will confine my attention herein to those intrinsic injuries to the knee which are seen frequently as the result of athletic participation, primarily to injuries to the ligaments and secondarily to injuries to the meniscuses.

It must be remembered that a ligament is a fibrous structure designed to prevent abnormal motion of a joint. Any injury to a ligament caused by abnormal motion may be defined as a sprain. A sprain can vary from a complete dislocation of a joint with total loss of integrity of the ligaments at one extreme to a slight tearing of a few isolated fibers with no loss of function of a ligament at the other. Properly it should include avulsion of the ligament from bone with or without a small fragment of bone (sprain fracture), partial avulsion of the ligament from the bone, or tearing of the ligament within its substance either transversely, obliquely, or longitudinally. In the latter instance the ligament may be elongated although it may appear to be intact. Function of the ligament depends not only upon its strength but upon its length since a ligament which is over long does not carry out its function of preventing abnormal motion of the joint. Since we are primarily concerned clinically with the function of the ligament, it matters little in what way but a great deal to what extent this function is disturbed. It is apparent that the severity of the injury is of much more significance than the exact location or type of the tear. It follows that it is of prime importance to be able to determine the degree of loss of function of the involved ligament at the earliest possible moment.

The anatomical drawings will serve as a review of the ligamentous structures of the knee. (Figs. 1 and 2.) The knee consists essentially of two long bones meeting end to end with neither the deep ball and socket of the hip, nor the mortise and tenon of the ankle. The only bony stability of the knee derives from the fact that the lower part of the femur is a bipod with two separate distal condyles. In order to permit lateral instability one or the other foot of the femur must be lifted from the tibial plateau. This anatomical fact does serve to give lateral stability with much less strength of the ligaments than would be necessary if there were but a single condyle. The greater part of the stability of the joint depends upon the intricately designed and ingeniously arranged ligaments of the knee. The lateral ligaments and the posterior ligament (or capsule) are actually a part of the great investiture of the joint by ligamentous structures which are massive and very strong laterally and posteriorly but become thinned in front to form the patellar retinaculum and so permit motion of the joint. These ligaments are supported and

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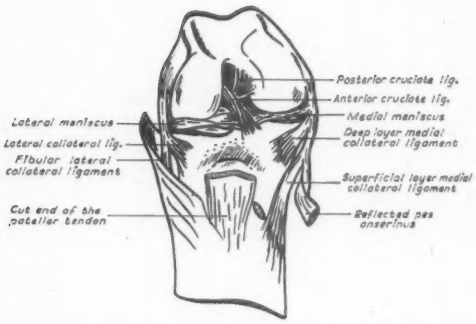

FIG. 1. Anatomic drawing of knee, anterior view. Patellar tendon is sectioned and the patella reflected upward. Knee flexed at 90 degrees.

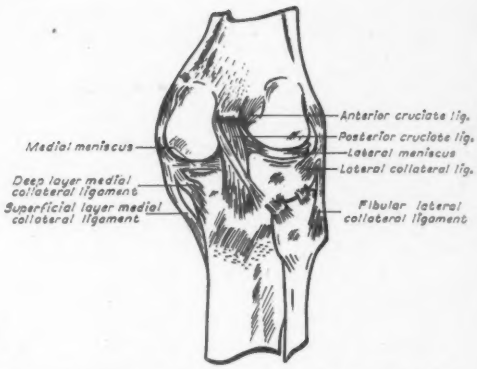

FIG. 2. Anatomic drawing of knee, posterior view. Knee extended.

their strength greatly augmented by the anterior and posterior cruciate ligaments which are very strong, fan-shaped structures, each twisted on itself and the two on each other to permit motion but to provide maximum stability. The anterior cruciate ligament arises anteromedially from the tibial plateau in front of the anterior tibial spine and extends backward, upward and outward to attach to the femur posterolaterally in the intercondylar notch on the medial side of the lateral condyle. While it has other functions, its primary function is to prevent forward displacement of the tibia on the femur. The posterior cruciate ligament arises from the midline of the back of the tibia, actually posterodistal to the articular surface. It extends forward, upward and inward to attach to the anterior part of the intercondylar notch on the medial side (lateral surface of the medial condyle) just adjacent to the articular margin. The primary function of this ligament is to prevent backward displacement of the tibia on the femur. All of the ligaments of the knee are tight in complete extension of the knee and this is the position in which the knee is the most stable, with both collateral ligaments, the cruciate ligaments (hereafter referred to as collateral and cruciate) and the posterior capsule taut. Varying degrees of relaxation occur in the different ligaments as the knee is flexed. This is particularly exemplified by the posterior capsule which loses its stabilizing function completely with only a few degrees of flexion of the knee. A detailed anatomical survey is not possible herein. It suffices to say that these ligaments do act synergistically and do act to support each other in preventing abnormal mobility of the knee while at the same time permitting normal motion. Functionally the knee joint is a hinge joint although anatomically the motion is much more complicated than this. The ligaments of the joint are so designed as to prevent abnormal lateral motion, abnormal rotatory motion, and abnormal forward and backward displacement of tibia on femur. The heavy posterior ligament serves to prevent overextension of the joint.

Sprain of the knee is caused by an abnormal motion of the joint which throws stress on the ligament or ligaments designed to prevent this motion. Forced motion beyond this normal limit will result in some degree of injury to the ligament primarily involved. This motion may be in any direction: adduction or abduction, overextension, internal or external rotation, forward or backward displacement, or various combinations of these. Certain particular combinations are more frequent than others. Much depends upon an accurate evaluation of the nature of the force applied. Knowing the manner of injury may give an indication of the type of ligament damage to be expected. In one classic injury, the foot is fixed to the ground, the thigh rotates inward and the leg outward, the knee is forced inward toward the opposite leg and the stress is primarily received on the ligaments on the inner side of the knee. (Fig. 3.) This is the most common type of athletic injury of the knee. What may we expect in the way of injury if it is known that this accident occurred by the familiar lateral blocking, or by the "cut back" motion of the running athlete? As the foot is forced into external rotation, stress comes against the medial collateral ligament of the knee, the superficial layer of which takes

FIG. 3. Photograph illustrating the forces causing "The Unhappy Triad," namely, the medial collateral ligament, anterior cruciate ligament, and the medial meniscus.

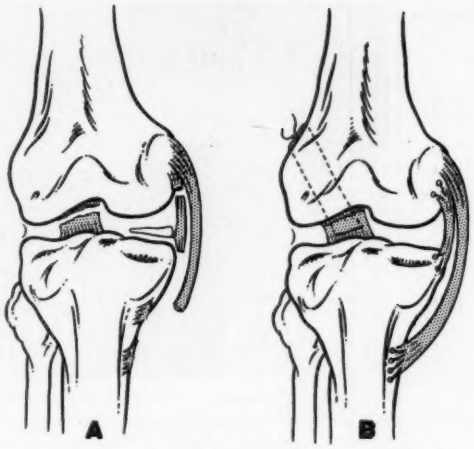

FIG. 4. A, drawing of injury to the medial side. (The injury received in the photograph in Figure 3.) It should be noted that the anterior cruciate ligament is pulled off its femoral attachment. A portion of the deep layer of the medial collateral ligament is torn off the femur, another portion is torn off the tibia and the superficial layer is torn off its lower tibial attachment. The medial meniscus is torn. B, the repair. (From: O'DONOGHUE, D. H. Surgical treatment of fresh injuries to the major ligaments of the knee. *J. Bone & Joint Surg.*, 32A: 721, 1950.)

the strain first. As this stretches, tears, or gives way, the force damages the deep layer to which is attached the medial meniscus. If the force continues, the anterior cruciate receives the stress and it too may fail. In severe injuries, the posterior cruciate may also give way. We would expect in this case to find sprain of the medial collateral and anterior cruciate ligaments, and injury to the medial meniscus ("The Unhappy Triad"). (Fig. 4.) Hyperextension of the knee throws initial tension on the posterior capsule of the joint, followed by stress against the posterior cruciate ligament and the posterior part of the two collaterals as the hyperextension continues. Direct forward motion of the tibia on the femur will injure the anterior cruciate while the opposite motion will damage the posterior cruciate. Frequently, an accurate and detailed description of the nature of the injury is not available. However, if this description is obtainable, it is of considerable importance since it may give a definite lead and permit a ready diagnosis and consequently, early, definitive treatment.

The initial examination should be made as early as possible. A general evaluation of the situation is of considerable importance. An accurate history of the sequence of events immediately following injury will help to determine the seriousness of the injury. Some players will have continued to play subsequent to the injury while others will have had such severe disability that they were immediately disabled. In either instance the exact history given by the player himself may be of value. In particular, one should try to determine what force caused the injury. He should also inquire whether deformity was actually present since deformity would inevitably mean serious injury to the ligaments. Many times by the time the knee is to be examined the patient will be unable to straighten it. It is then important to determine from the player and from the coach or trainer whether or not the knee was locked at the time of the accident and later spontaneously or manually reduced. The knee will ordinarily completely extend immediately after the injury unless it is mechanically blocked since at that time muscle spasm and pain have not caused the flexed position to become fixed.

After such an evaluation one should proceed to the examination. It is important to emphasize that all clothing including taping or strapping should be removed from the injured part. Since the player may well be quite apprehensive I make it a practice to examine the normal knee first. This not only serves to

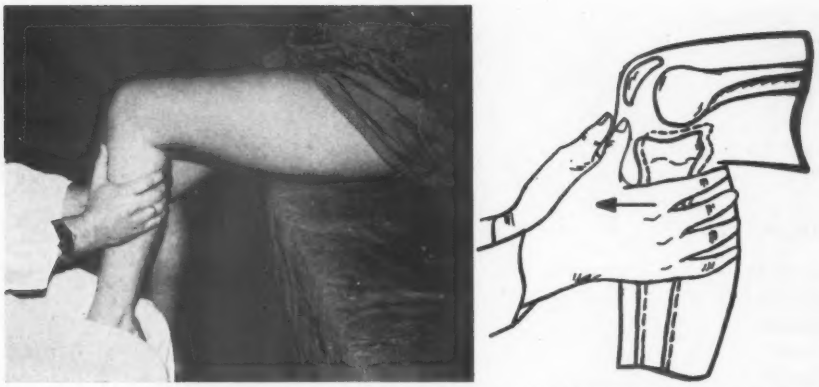

FIG. 5. The drawer test. Illustration of position with the foot held between the knees, the upper part of the calf grasped with both hands. The tibia can be displaced forward (anterior drawer) or backward (posterior drawer). Drawing illustrates anterior drawer.

allay his apprehensions and reassure him that you do not intend to grab the leg and jerk it around, but this will also provide an invaluable guide as to the normal stability and range of motion in this particular youth. Although they may seem quite mature physically many of these players have joints that are quite immature with a surprising degree of normal lateral and rotatory motion. The usual steps for physical examination of the joint involved are important, namely: observation to note any deformity, the degree and location of swelling, the presence of inflammatory reaction; palpation to determine the degree of tension both in the knee joint and the surrounding tissues, to elicit the presence or absence of fluid in the knee and particularly to determine as accurately as possible the location of this tenderness and pain. Careful manipulation is then in order. One should compare the range of motion of the injured knee with its normal fellow. Only after this gentle and careful examination should one try to determine the presence of instability. Gentle hands are an asset indeed if one is to obtain the most accurate information from an apprehensive patient. One should first carefully check the degree of stability with the knee in complete extension. This is the most stable position and the least likely to cause pain. However, if the knee is unstable in complete extension this is *prima facie* evidence of severe injury to the ligaments to a degree which would demand prompt, definitive treatment. Then, flex the knee about 20 degrees to a position of about 160 degrees extension. In this position the posterior capsule will be relaxed and the knee is normally more unstable than in complete extension. One would expect to elicit some increase in lateral mobility simply by slight flexion of the knee. This should be carefully compared with the opposite side and if there is a sharp increase in either lateral angulation of the tibia on the femur or medial angulation of the tibia on the femur, it is an evidence of loss of function of the opposite collateral ligament. One should also observe whether or not this abnormal motion is painful and if the pain is at the same location as the site of the tenderness. Often the knee which is being examined may have been previously injured so it is well to consider the possibility that the instability may have preceded this injury and not actually have been the result of this episode. The knee should then be further flexed preferably with the patient sitting with his legs hanging over the side of the table. I prefer to check the anteroposterior instability by seating myself in front of the patient, grasping his foot between my two knees and holding the upper part of his calf firmly in both hands. (Fig. 5.) Steady forward pressure should be applied to the upper part of the calf, not by jerking but by even pull forward and a similarly controlled push backward. This should first be carried out on the normal knee and then on the injured knee. A positive test is indicated by appreciably greater excursion of the tibia than normal. Usually the definite forward check is missing if the ligament is torn. In an acute injury it

may not be possible to flex the knee to such an extent that one can check for clicking of cartilage with the knee in complete flexion. If possible this should be performed. Such a careful examination will usually provide sufficient information to permit one to plan intelligent treatment of the injured part.

MILD INJURIES TO THE LIGAMENTS

In a mild injury to a ligament, there has been some tear in the ligamentous fibers but its strength has not been particularly impaired. There has been some degree of damage, either within the ligament itself or at one of its attachments. The symptoms of such a tear are: tenderness at the site of the tear, pain on active use of the knee, local swelling at the site of the injury, and pain on forced motion or on an attempt to duplicate the motion which caused the tear. Negative findings of significance are: no instability, no blood in the joint or infiltrated through the tissues, no effusion, no locking, and no pain on normal motion.

Provided one can be sure that it is a mild injury, treatment may be based on the premise that the strength of the ligament is basically unimpaired. In this type of injury to a ligament prolonged and extensive treatment is not necessary. Fortunately the great majority of injuries to ligaments falls into this group. They seldom reach the doctor and practically never the specialist. The basis of treatment is, first, protection against further injury and, second, reduction of local tissue reaction. Immediate application of a pressure bandage with an ice pack will minimize local swelling. These are the cases in which apparently dramatic results may be obtained by local treatment. Even spraying with ethyl chloride may seem valuable. Local anesthesia inserted into the injured area will reduce pain and vessel spasm. Injection of hyaluronidase into the hematoma will speed absorption and reduce swelling and ecchymosis. Protective strapping will permit prompt resumption of activity. Complete immobilization is neither necessary nor desirable. The patient may be rapidly rehabilitated without danger. Warning—since the diagnosis may not be entirely certain at the time of injury the player should not be permitted to participate in sports immediately after local anesthetic has been injected. The injection may screen his symptoms and permit reinjury.

MODERATE INJURIES TO THE LIGAMENTS

In the second group, the moderate injury to a ligament, it is postulated that the ligament has been partially torn. This group actually includes most of the sprains which require extensive treatment since it is all inclusive, from those that have a very slight tear to those which have only a few intact fibers remaining. A certain portion of the ligament has been damaged and its strength is impaired to a greater or lesser degree. The symptoms are very similar in pattern to those of a mild injury. They are greater in degree but each of these groups shades imperceptibly into the other. The positive findings are: pain in the knee; tenderness at the site of the injury; disability of a greater degree than in the mild type; swelling at first localized at the area of damage, later spreading to become a diffuse swelling about the joint; fluid or blood in the joint; and pain on reproduction of the force and direction of the injury. There may or may not be locking due to damage to the meniscus. The findings which are not present in a moderate sprain are excess lateral motion and increased anteroposterior slipping of the tibia on the femur with the knee flexed (positive drawer sign). Each of the latter two tests indicates complete loss of function of a ligament permitting abnormal motion and is not positive if the severance of the ligament is only partial.

Treatment is based upon the premise that there has actually been significant damage to the ligament with weakening of its structure and considerable loss, or at least potential loss, of function. Therefore, treatment must be more comprehensive than in the mild group and the emphasis is on protection from further injury. A firm compression bandage should be used and an ice pack applied. Local treatment consists of aspiration of the local hematoma or of the knee joint followed by injection of some long-acting local anesthetic. Hyaluronidase mixed with the anesthetic agent is valuable if hemorrhage is recent. Since the exact degree of injury may not be readily apparent one must protect the joint against further insult as long as symptoms persist. Bleeding is reduced by immediate compression with an elastic bandage and the application of ice.

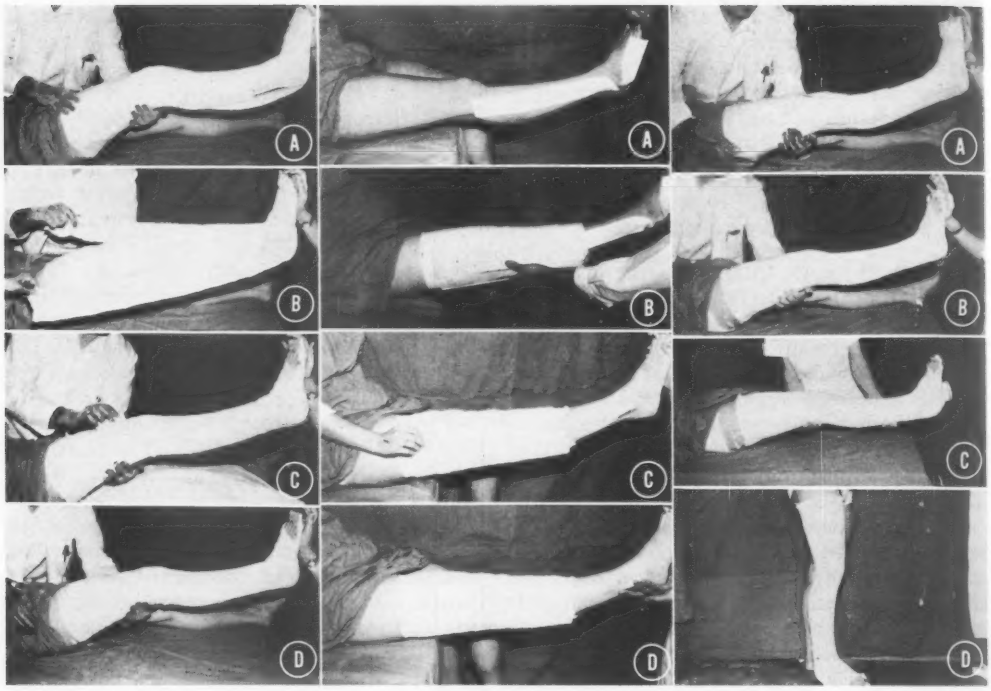

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FIG. 6. Long leg plaster splints (posterior and lateral stirrup). A, the knee positioned at 30 degrees of flexion (150 degrees); supported under the thigh and by the foot to permit the tibia to drop backward. Posterior plaster splint applied from the gluteal fold to beyond the toes. B, posterial splint wrapped snugly in position with 3 inch gauze (foot supported at 90 degrees); lateral stirrup applied from the upper inner part of the thigh to the trochanter. C, the plaster splints are snugly wrapped with gauze bandage. Immediately postoperatively a circular plaster bandage is wrapped about the knee. This is removed in a few hours. D, the finished splint. (For anterior cruciate repair the knee is supported by the foot and thigh with no support under the calf.

FIG. 7. Cotton cast. A, the leg is shaved from the knee to the ankle, 3 inch adhesive strip applied to either side. B, the knee is wrapped in regular sheet wadding, usually five or six rolls, slightly longer than the length of the yucca board. A moistened yucca board splint is applied on either side and posteriorly, centering at the knee. C, yucca board splints have been wrapped snugly in place with 3 inch gauze. The two adhesive strips are pulled back snugly over the ends of the two lateral boards. D, the finished cotton cast, the adhesive strips having been wrapped down snugly with gauze and the whole protected by spiral 1 inch adhesive tape.

FIG. 8. Long leg walking cast. A, the leg is wrapped in sheet wadding or webril from the toes to the groin; the posterior plaster splint is applied from the gluteal fold to beyond the toes with the foot at right angle. (Note: for anterior cruciate repair the knee is supported by the foot and thigh with no support under the calf.) B, circular plaster is applied in the usual manner with the knee at approximately 20 degree flexion. C, with heel applied. D, illustrating the length of the cast from the groin to the gluteal fold.

Later (Fig. 6), plaster splints, graduating to a cotton cast (Fig. 7) and finally to an elastic wrap, as symptoms permit, will serve to promote healing and prevent further injury. If effusion in the joint persists, aspiration should be repeated as often as is necessary. Aspiration of bloody fluid should be followed by injection of hyaluronidase. Following aspiration of cloudy fluid the injection of some type of corticoid preparation is of value in reducing chronic synovitis. Protection must be maintained and insisted upon as long as symptoms persist. Contact participation should not be permitted without firm adhesive strapping. Strapping serves to protect the ligaments of the knee better than any type of compression knee bandage currently available. It is difficult to generalize as to how comprehensive treat-

ment should be in a given case but it is quite apparent that the sprain which causes only moderate damage will not require as extensive or as prolonged treatment as that which is more severe. To a large extent this must depend upon the judgment of the physician. As a rule treatment with compression and ice packs should be continued for several hours or even longer if the swelling is severe. Systemic use of some of the enzyme preparations may be of value (such as thymar administered intramuscularly or buccal varidase administered under the tongue). With discontinuance of the compression bandage and ice pack, the decision should be made as to whether the injury is severe enough to require plaster splints from groin to toes or some type of coaptation splint from mid-thigh to mid-calf (such as the cotton cast). If the ligament is actually torn it will require at least three weeks for healing and there should be some period of protection following this. Here again this must depend upon the degree of the damage, since if the greater part of the ligament is intact, the undamaged part of the ligament may serve to protect the injured portion. If the defect is a major one, a longer period of external protection will be indicated to prevent reinjury. The posterior and stirrup long leg splints may be worn from seven to ten days and then be replaced by a long leg walking cast (Fig. 8) for another ten days. This may be followed by short splints to be followed in turn by an elastic bandage, particularly if swelling or effusion persists. It merits repeating that the knee capsule should not be permitted to remain distended over a long period of time and that the necessary aspirations should be carried out even if it is necessary to do this many times. It should be emphasized again that aspiration of the knee should be carried out with the same aseptic precautions one would use if the knee joint were to be opened surgically. I prefer a thorough soap and water scrub, protective draping and the use of sterile gloves. One need not fear infection if he anticipates its possibility and takes the proper preventative measures.

There is considerable difference of opinion as to the length of time the ice pack is beneficial. It does diminish bleeding and does slow down metabolism. Therefore, it should be continued as long as these two ends are desirable. In the ordinary case bleeding will stop after a few hours. At this time it is desirable to increase metabolism by the local application of heat. This may be in the form of an electric pad, diathermy or a hot bath. If a well equipped and well controlled training room is available the dressing may be removed daily for the application of heat and controlled physical measures such as use of the whirlpool, massage or careful motion. This must be under the protective eye of a qualified trainer or physician.

Rehabilitation is extremely important in this type of injury. Controlled physical therapy such as diathermy, the use of a whirlpool or electric heating pad, is of value in improving circulation. A program of gradually increasing active function should be initiated early and particular attention should be paid to the other joints in the extremity. Muscle setting exercises for the quadriceps, hamstrings, calf, are all important. As immobilization becomes less, a definite program of functional exercises should be utilized. Meanwhile complete immobilization is replaced by protective strapping until healing is complete. Unwise overuse of a knee which has persistent effusion or persistent tenderness at the site of the injury will often delay complete rehabilitation for many weeks. On the other hand, overextensive immobilization, prolonged beyond the time when protection is important, will also delay recovery. Reduction of pain and swelling by local injection must not be permitted to conceal the true nature of the injury. Active stress on the involved ligament must not be allowed until the healing of this ligament is complete. Ordinarily complete recovery should be expected with no disability in the joint if the treatment has been adequate. By far the major number of injuries to ligaments will fall into the first and second groups. There is no justification for limiting the activity of the patient once healing is complete. It is the unusual or exceptional case in which there should be permanent disability from a moderate sprain. The popular lay conviction that "once a sprain always a sprain" is indeed a reflection on the inadequate medical care so frequently given to this condition.

SEVERE INJURIES TO THE LIGAMENTS

A severe injury to a ligament is one in which there has been complete loss of function of one or more of the major ligaments of the knee.

This tear may be through the ligament but more frequently it is at one or the other of its attachments; the most frequent tear is to the medial collateral ligament, particularly at its superficial tibial attachment which lies about 3 inches below the knee on the anteromedial face of the tibia. A complete tear presumes some degree of dislocation or separation of the joint. If the force applied is greater than the strength of the ligament to resist, the ligament gives way. If the force continues a succession of ligaments give way depending upon the direction of the force. There is ordinarily immediate disability, usually quite severe. The player will often say that his knee has given way or that it has actually been dislocated. The extremity may be extremely painful. The patient may have to be carried from the field. If examination is carried out early one can determine the location of the tear very accurately by tenderness at the site of the tear and pain at this area on careful manipulation of the knee. If the injury is severe enough the joint may not fill with blood since the joint capsule will be disrupted and the blood infiltrates through the tissues rather than pooling within the knee. If the knee is examined very early swelling will be localized at the point of the tear and one can frequently determine accurately the site of one or more injuries to the ligament. In the common injury to the medial side of the knee caused by external rotation and abduction of the tibia on the femur with the knee slightly flexed, the tenderness will frequently be at the site of the attachment of the medial collateral ligament some 3 inches below the knee and may be mistaken for a contusion. (Fig. 4.) This same patient, however, may have another site of tenderness either at the tibial margin or at the femoral condyle depending upon the damage done to the deeper layers of the ligament. At this stage one may readily determine lateral or anteroposterior instability. Locking is usually not present in the severe injury since the very fact that the knee has lost its stability makes it less likely that the cartilage will remain displaced. The single most important finding in the determination of severe injury to the ligaments is abnormal motion. While this is the picture ordinarily found in the tear of the collateral plus the cruciate ligaments, it should be borne in mind that the cruciate ligaments can be torn with no symptoms of lateral instability and actually with very little reaction about the knee. One may be chagrined to determine after the so-called "moderate sprain" of the knee has recovered that there is complete loss of function of one or the other cruciate ligaments.

There are certain patterns of symptoms which accompany certain types of injuries to the ligaments and a few of these might be worth mentioning. It should be emphasized particularly that the medial collateral or lateral collateral ligaments can be completely removed and the knee will remain stable when it is placed in complete extension. The posterior capsule and cruciate ligaments are great stabilizing factors with the knee in extension. When the knee is slightly flexed and the posterior capsule is relaxed then loss of function of the collateral ligament will result in increased mobility of the knee even though the cruciates are intact. One should familiarize himself with the function of the various ligaments in order that he may intelligently check the knee for loss of function of the ligament. I would like to emphasize again that it is extremely important to examine the knee carefully for anteroposterior instability of the tibia on the femur. I cannot overemphasize the importance of this test. In many instances one will be unable to check the cruciates after several hours have elapsed because the knee will be swollen and painful and cannot be bent to a sufficient angle to permit an accurate test. If one is going to operate upon the knee for some other reason such as a torn semilunar cartilage or loss of integrity of the collateral ligaments this is not too important because the cruciate can be examined at the time of surgery and proper measures carried out. If, however, the decision as to whether or not to operate is going to depend upon preoperative determination of cruciate instability, one is justified in giving a light anesthetic or sufficient narcosis to permit a careful test. It must be realized that strong contraction of the hamstring tendons may result in a negative test for forward displacement of the tibia on the femur (anterior drawer sign), so it is extremely important that the patient be relaxed at the time the test is made. Examination should be made at the earliest possible moment. We have been able to show that early repair of the cruciate ligament is quite successful (Fig. 9) whereas late repair and reconstruction present a much more

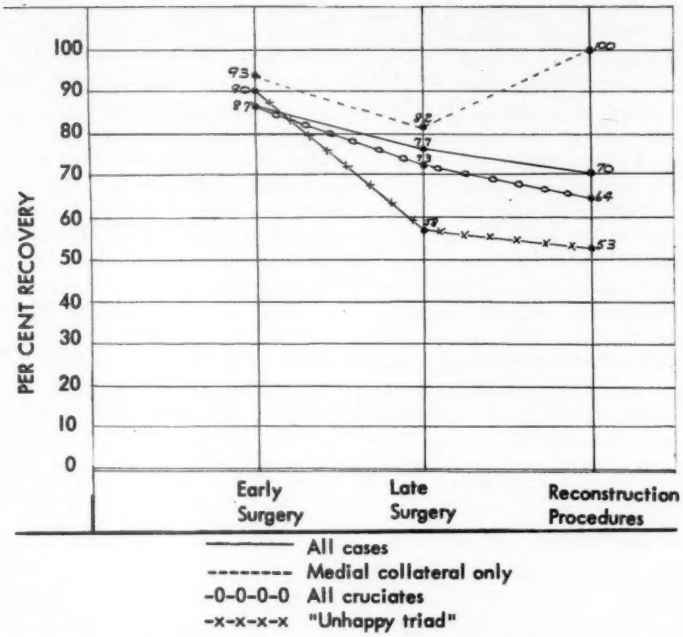

FIG. 9. Figure showing end results of operations on ligaments of the knee. (From: O'DONOGHUE, D. H. An analysis of end results of surgical treatment of major injuries to the ligaments of the knee. *J. Bone & Joint Surg.*, 37A: 1, 1955.)

serious problem with much less favorable results.

Treatment of the Severely Sprained Knee. If one has been able to determine with reasonable confidence that there has been a complete tear of any single ligament of the knee one should treat it by surgical repair. Fortunately the vast majority of injuries to the ligaments of the knee do not result in complete loss of function of the ligament, so that the ligament may partially tear and the fibers remain in sufficient continuity that one may expect a good spontaneous repair with little, if any, redundancy of the ligament involved. This most frequently involves the collateral ligaments and the redundancy may be corrected by a later plication operation providing that good ligamentous substance remains. However, if the ligament is completely torn or avulsed one not only faces the practical assurance that there will be overlength of the ligament but in many instances ends of the ligament will be so widely separated that union does not occur at all. This is almost uniformly true with the cruciate ligaments. The knee joint does not tolerate loose ends of ligament within the joint and these ends rapidly retract and in effect chondrify so that when one opens the knee at a later date he finds not only wide separation of the ligament ends but extremely inadequate ligamentous material. Even were it possible to get the ligament ends together in such a case reparative processes would not result in healing by normal ligamentous tissue. We have shown not only in clinical surgical cases but also by experimentation on animals that without exception cruciate ligaments which have been completely severed do not repair unless they are surgically replaced. While I believe that any completely torn ligament should be repaired, surgically, this is particularly vital for the cruciates.

We have been able to show that surgical repair of the cruciate ligament may result in a normally functioning ligament of normal strength provided the repair is performed early (within ten days). The surgeon should determine as accurately as possible the location of the tear, and the exact technic for the repair must vary according to the ligaments found to be damaged. Even though at the time of surgery

the ligaments seem to be badly chewed up and with multiple areas of separation and avulsion, one will find at the end of a very careful, meticulous repair that he has assembled a surprisingly good mass of ligament. This will result in a minimal amount of scar formation which will rapidly metamorphose into normal ligament, whereas wide separation of these fibers with an intervening mass of dense, fibrous scar will usually not evolve into normal ligamentous tissue at all. In fact, in our experimentation on animals we have been able to show that the healed area of a repaired ligament is stronger than the adjacent ligament, whereas the scarred area of the separated ligament ends is the weak link in the chain. There is no justification for carrying out surgery on the joint and not repairing the cruciate ligaments if they are reparable, and they usually are if the operative date is within two weeks of the time of the injury.

While repair of the cruciate ligaments may present some difficulties, it is not beyond the capacities of the well trained surgeon; in my opinion a surgeon should not operate on a knee unless he is prepared to carry out whatever procedures may be necessary any more than a surgeon should permit himself to open an abdomen and not be prepared to cope with whatever pathologic condition is found.

The detail of surgical repair is well covered elsewhere but a brief statement might be in order in regard to postoperative management. As the repair is completed the knee is carefully checked on the operating table to determine the degree of actual stability resulting from the repair. In the usual case the knee will be remarkably stable. We are careful not to put undue stress on the cruciate ligaments since our problem here is mainly to effect apposition of the ligament ends and frequently the suture line may be relatively unstable. This is not true of the collaterals.

Following surgery I prefer to use a heavy posterior plaster splint carefully positioning the knee at about 150 to 160 degrees extension. If the anterior cruciate has been repaired the extremity should be supported under the thigh and under the heel rather than under the calf. (Fig. 6D.) If the posterior cruciate has been repaired the opposite is true; that is, the leg should be supported under the calf rather than under the thigh. After the posterior splint sets to some degree, a lateral stirrup is applied from the inner upper part of the thigh around the foot and up to the trochanter. I prefer to use this type of splint since there frequently is considerable postoperative swelling and the splint can be loosened to accommodate this swelling and promptly tightened as the swelling goes down; also, some idea as to the amount of effusion in the knee can be obtained through the dressing so that if it seems too tight the dressing can be partially removed to determine if aspiration of the knee is indicated. In ten to fourteen days when the reaction to the injury and operation has subsided this long leg posterior and lateral stirrup splint is removed and a long leg plaster cast applied.

Rehabilitation is started immediately postoperatively, and the patient is ordinarily allowed to get out of bed on the following day. We begin his instructions in quadriceps setting and active use of both lower extremities immediately. By the end of two or three days he should be able to raise his leg actively from the bed and he should do this at intervals throughout the period of his convalescence. Depending upon the degree of postoperative reaction he is allowed to be on crutches at about the second to the fourth day. After the stirrup splints have been replaced by the long leg cast, activity is increased. He wears long leg support up to four weeks postoperatively. At this time one may presume that the ligament has healed but that it has not entirely regained its normal strength. We replace the long leg cast with a cotton cast or similar dressing which extends from mid-thigh to mid-calf and permits some motion but still gives considerable lateral support. This is ordinarily worn for another two weeks, a total of six weeks postoperatively, and then support is discarded unless an elastic bandage is needed because of effusion in the knee.

Aspiration is carried out whenever the knee joint seems to be unduly distended. If aspiration is carried out early and blood is encountered, hyaluronidase is injected. Aspiration of cloudy joint fluid is followed by injection of an appropriate corticoid. In my opinion aspiration should be repeated as often as is necessary to reduce the tension within the knee. In some cases it may be necessary at weekly intervals, however not in the average case. It is important to give the patient definite instructions in rehabilitation. (Fig. 10.) He should not be expected to manage his own treatment.

What kind of results should be expected fol-

REHABILITATIVE EXERCISES FOR THE QUADRICEPS MUSCLE FOLLOWING INJURY TO OR OPERATION ON THE KNEE

1. Sit on the side of the table with the legs hanging in a vertical position.

   A. Raise the foot on the involved side to the horizontal position slowly to the count of three seconds, resting thigh flat against table.
   B. Hold leg in horizontal position to the count of three seconds.
   C. Lower leg slowly to the count of three seconds.
   D. Rest for the count of three seconds.

2. Repeat this ten times. Rest a little.

3. Do this through three series of ten times each, i.e., thirty times total.

4. These exercises should be repeated two or three times a day depending upon your tolerance.

5. When you are able to complete the series of thirty elevations, add light weight to the foot at the next period of exercise and raise this weight until you can do the exercise the full thirty times.

6. Continue these exercises, adding weight successively according to your tolerance until you are raising 25 or 30 pounds through this series. The opposite knee may be used for control to get some idea of how much you should expect to raise on the injured leg.

7. Make a chart of your daily progress and record on it each period of treatment, noting the ascending curve of your weight-lifting capacity.

8. These exercises should be continued until the circumference of the involved thigh is the same as the normal thigh, and until you are able to raise as much weight as you can on the uninvolved side. As your strength increases, these exercises should, of course, be supplemented by other exercises, such as going up and down stairs, partial knee bends, single knee bends, etc.

FIG. 10. An example of the type of instructions in rehabilitation given to the patient following injury to or operation on the knee.

lowing major injury to the knee? I think one should expect a normal knee. It may not always be possible to obtain 100 per cent recovery but certainly this must be our goal. In our series of patients very carefully checked we found that in the great majority with complete tears of ligaments treated surgically at the time of injury the patients returned to whatever degree of activity they had had before their injury. Football players returned to playing football; high jumpers returned to high jumping. We found, moreover, that the single most important element in the success of surgical repair was the interval between the time of the injury and time of surgery. Almost uniformly if the surgery was performed within a week or ten days, and certainly the sooner the better, the results were good. In fact in many instances there were better results for patients with major injuries than for those with less severe injuries since in the former the injury was quite obvious and surgery was promptly carried out. The results of early surgery are extremely gratifying. Delayed surgery may be necessary to overcome disability because of faulty early diagnosis but the results are not nearly as satisfactory as those of early surgery.

INJURY TO THE MENISCUS

Another common condition which I think should be discussed is injury to the meniscus. This injury goes hand in glove with the sprained

ligament. The general structural anatomy of the meniscuses is well known but it is well to recall certain significant differences between the two meniscuses in order to clarify the damage one may expect from a given type of injury. It will be recalled that the medial meniscus is C shaped. Its anterior attachment is on the top of the tibia in front of the tibial spine; the posterior attachment is on the top of the tibia behind the posterior spine. In each case the attachment is relatively near the periphery of the tibia so that the two ends are quite widely separated from each other. It is attached by means of the coronary ligament all the way around the top of its periphery to the medial collateral ligament and hence to the tibia. This attachment is firm and while it does allow a little play there is no very extensive motion permitted in the normal medial meniscus.

In a sprain of the medial collateral ligament, the tibia and femur tend to separate on the medial side and stress is applied in the area of the attachment of the cartilage to the medial ligament. The cartilage may be forced to accompany either the femur or the tibia depending upon the location of the injury to the ligament. Since the structure of the meniscus does not allow too much bending stress, it will tear transversely or more commonly split around its periphery. If the tear is actually in the attachment of the ligament this will frequently heal. If the tear is within the substance of the cartilage it will not. In my experience injury to the cartilage more frequently accompanies repeated sprains to the knee than the initial single sprain. I know of no way to determine in an acute injury whether or not the cartilage is torn unless the knee is actually locked. If the knee is locked, the ligaments appear to be stable and this is the first episode, one may be justified in attempting to reduce the displacement by very careful manipulation. If the cartilage has been detached at its periphery this attachment may then heal. This possibility is much more likely if the cartilage has slipped in and locked and has been almost immediately unlocked. Such an incident occurs when the player hurts the knee and it is manually forcibly extended immediately following the injury and the cartilage snaps back in place. My own opinion is that if the knee actually locks even one time it should be operated upon, and the cartilage should be examined and removed if torn. However, I have no particular argument with the surgeon who prefers to wait for the second episode. There is nothing to be gained by waiting for repeated episodes of locking. We have been able to show that locking of the knee because of intrinsic pathologic disorders has a definite deleterious effect on the cartilage of the joint, not only on the condyles of the femur and tibia but more particularly on the patella; thus, the surgeon must not condone the patient who brags of repeated locking of his knee. I believe one is not justified in encouraging this by manipulative reduction of the locking on more than one or two occasions. Careful explanation to the patient of the deleterious effects of the locking episodes will ordinarily convince him that he would rather have his knee operated upon early and expect an excellent result than undergo surgery after malacia has become advanced.

Whereas the medial meniscus is C shaped with widely separated anterior and posterior attachments, the lateral meniscus is almost O shaped, its anterior and posterior attachments being deep in the tibial notch and very close to each other, in many instances continuous with each other. The coronary ligament is much less firm and is more redundant. The cartilage is not attached to the fibular collateral ligament. Therefore, more motion is permitted in the lateral meniscus than in the medial meniscus. Injury to the lateral side of the knee is less common than to the medial side; in addition to this, the cartilage is much less likely to be damaged by acute lateral stress so that not frequently does one see a tear in the lateral meniscus in conjunction with an acute sprain of the knee. On the other hand, by virtue of the looseness of the cartilage, particularly its posterior portion, it is quite vulnerable to chronic damage so that it is more likely to be hurt by repeated forced flexion of the knee than by lateral strain. Frequently, the damage comes on insidiously as a result of squatting with the heels against the buttocks for long intervals at frequent times. I have been so impressed with the vulnerability of the lateral cartilage because of the redundancy of its posterior third that I do not recommend deep knee-bends or so-called "duck waddle" as training measures. As the knee goes into complete flexion the back of the cartilage may be caught between the impinging femoral and tibial condyles and pinched forward, as one would pinch an apple seed between his finger tips. This strains the posterior peripheral

attachment until finally the meniscus may actually snap in front of the femoral condyle, progress to the typical bucket handle position and lie within the notch in front of and medial to the femoral articular condyle.

If one never makes the diagnosis of injury to cartilage until the knee has undergone repeated locking one is of necessity overlooking many torn meniscuses! The diagnosis of injury to the cartilage may be made by the patient's history alone and it is extremely important that the history be carefully and objectively taken. It is wise not to put words in the patient's mouth. If he gives a definite, detailed and reliable history of locking of the knee, one may assume damage to the meniscus until it can be proved otherwise. The more difficult problem is the case in which the knee gives chronic trouble with recurrent effusion and recurring periods of disability but with no locking or "giving away." One suspects damage to the meniscus. In this instance a very careful examination will be of extreme value. There is usually tenderness along the joint line in the area which is damaged. This may be posterior as a result of posterior tearing or may be mid-lateral or may be in front. The various manipulations which put stress on the cartilage should become familiar to the examiner. With the knee semiflexed lateral stress may cause pain although in the older injury to the cartilage this may not be painful. There is usually pain on rotatory stress. With the knee slightly flexed, the calf is grasped firmly and the leg rotated laterally and medially. Pain will frequently be noted at the exact site of the injury to the meniscus. One can at least determine which side of the knee is involved. The various types of "cartilage click," such as the Ledbetter tests, are of importance if elicitable. Another test which I think is quite valuable is performed with the patient prone. The knee is placed in complete flexion and then hyperflexed to determine if this causes pain and where the pain is located. Many patients with posterior tear will have a definite cartilage click on this maneuver. In the same position the foot is turned into external rotation and the knee flexed and extended. Consistant clicking in these tests must be considered significant. In the final analysis, the knee which stubbornly resists conservative treatment and in which a pathologic condition of the cartilage is suspected justifies arthrotomy. This is not to say that every knee which is painful should be operated upon. The weight of the evidence must point toward damage to the meniscus to justify surgery.

I have previously said that the locking of the knee is in itself justification for surgery. The locking may be due to damage to the meniscus. It may be due to a foreign body in the joint, displaced osteochondritis dissecans, etc. On arthrotomy one must be prepared to treat whatever pathologic condition is found. If the knee locks some presumptive cause must be found at surgery if the operation is to be successful. Removing a normal meniscus will not stop the knee from locking.

The details of surgery will not be discussed herein since they are available in many places. Some general principles might be reiterated. I think there is no justification for removing a normal meniscus just because one has diagnosed a pathologic condition of a meniscus preoperatively. If one examines the front of the meniscus and it appears to be normal there may indeed be a posterior involvement. It is pretty drastic to detach the anterior end of the meniscus in order to determine if the posterior portion is torn. A better procedure is to approach the knee behind the medial collateral ligament and so inspect the posterior part of the meniscus. It is not only unjustifiable to remove a normal meniscus but a more pertinent point is that, the pathologic condition which is causing the trouble in the knee has not been eliminated if a normal cartilage is removed. If both cartilages are inspected and there is no abnormality of either, the knee should be carefully explored for other pathologic disorders. It is the unusual case in which careful search will not demonstrate some condition which will account for the symptoms. This may or may not be remediable but certainly is not helped by removing a normal meniscus.

The big question is, what constitutes a "normal" meniscus? Here is an area in which surgical experience is extremely valuable. I have no hesitation in removing a meniscus which is yellow and sclerotic or in which there is redundancy of one or the other attachments although there may be no obvious tear. However, I would feel extremely uneasy about removing a sclerotic meniscus in a knee in which there is history of locking or giving way since certainly a sclerotic meniscus could not be expected to cause these findings. Frequently at arthrotomy there will be found a rather marked

redundancy of the fat pad, the posterior margin of which may appear grossly sclerotic. In my opinion this can be symptomatic, usually causing pain on forced or rapid extension of the knee. However, I again feel a little uneasy about simply trimming away the fat pad unless I can assure myself that there is no other pathologic conditions in the knee. Symptoms relating to the fat pad should be around the pad and elicited by pressure on this area or pinching.

I realize that this is a vast oversimplification of the problem of the meniscus but I would like to reiterate a few of my own convictions: (1) A locking knee should be operated upon regardless of freedom from symptoms in the intervals between episodes. (2) Authentic giving way of the knee may be almost as significant of damage to the meniscus as is locking. (3) A careful history suggestive of damage to the meniscus supported by findings indicative of a pathologic condition of the meniscus justifies arthrotomy provided there is real disability of the knee. If the symptoms are so mild as to cause no effusion, instability or actual disability from pain, arthrotomy may be postponed since the knee is not undergoing deterioration because of delay. However, if the condition is truly disabling to that particular patient arthrotomy may be justified to improve his function.

Many other intrinsic conditions of the knee such as osteochondritis dissecans, chronic synovitis, traumatic arthritis and chondral fractures may occur from athletic injuries. One of the most frequent sources of pathologic distûrbances of the knee is chondral fracture of the patella which in my opinion is frequently the cause of so-called "patellar malacia" in young people. This is an extensive problem in itself. It suffices to say that if symptoms center around the patella and are persistant and unrelenting after careful conservative management, one is justified in inspecting the patella surgically. Very gratifying results follow partial chondrectomy of the patella if the condition is actually due to trauma. In some instances I have seen at arthrotomy large fragments of cartilage knocked off the patella in spite of negative x-ray findings, but with symptoms suggesting damage to the meniscus. The locking in this instance was the result of the foreign body within the knee.

In conclusion I would like to emphasize again that to treat successfully traumatic conditions of the knee which result from athletics one must familiarize oneself with the detailed structure of the knee and the forces involved in the injury, one must be prepared to accommodate the treatment to the exact pathologic condition found rather than to treat all patients by the so-called conservative "trial and error, wait and see" method. As in other pathologic conditions intelligent treatment must be based on an accurate understanding of the specific situation in the particular athlete. Generalization can only give some percentage of good results. The athlete must have 100 per cent recovery in each case.

Fractures and Ligament Injuries of the Ankle

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MAN has not wholly adapted to bipedal existence and until he does, a few hundred thousand years hence, the ankle will remain one of the most vulnerable sites of musculoskeletal injury. Being what he is, man has never been content with the *status quo* but has always felt impelled to climb mountains, run races and take part in vigorous games, thus further increasing his chances of injury. Some sports seem ideally designed to hurt the ankle. Football, soccer and basketball involve quick turns on a fixed foot, and skiing adds the enormous power of an eight-foot lever strapped to the sole.

It is most unlikely that any change could be made in the basic spirit which makes men put their bodies to such tests. It would indeed be most undesirable. It therefore becomes necessary to accept the fact that injuries will occur in athletics and to survey the problem from the points of view of prevention, diagnosis and treatment.

PREVENTION

The best way to avoid injury in any sport is to become proficient in its technics and to be in the best possible physical condition. The really good athlete is rarely injured and then only under unusual circumstances. However most participants in sport are not outstanding nor are they gifted with perfect bodies. For these, a great deal of protection to the ankle is afforded by regular use of ankle wraps. (Fig. 1.) Applied by the player himself over the inner of two pairs of socks with a turn around the heel, these non-elastic bindings effectively limit lateral mobility without interfering with flexion or extension [1]. There is good evidence that when these bindings are worn regularly the incidence of injury to the ankles can be reduced at least 50 per cent [2].

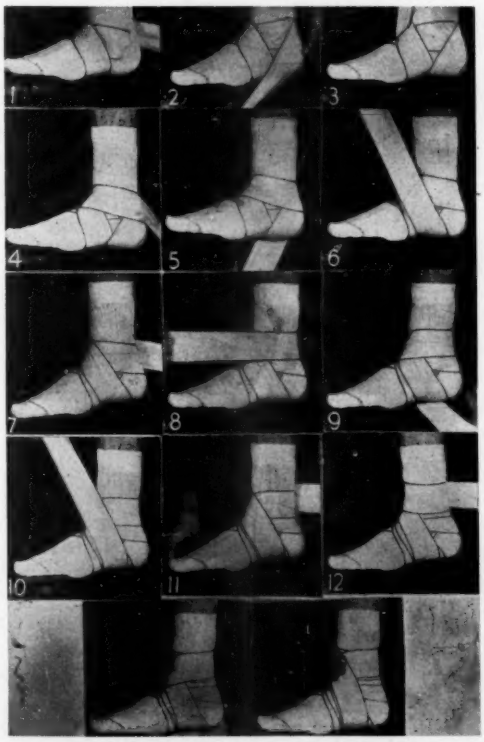

FIG. 1. Steps in application of non-elastic ankle wrap, for protection. Note turns around the heel which limit lateral mobility. (From: QUIGLEY, T. B., COX, J. and MURPHY, J. *J. A. M. A.*, 132: 924, 1946.)

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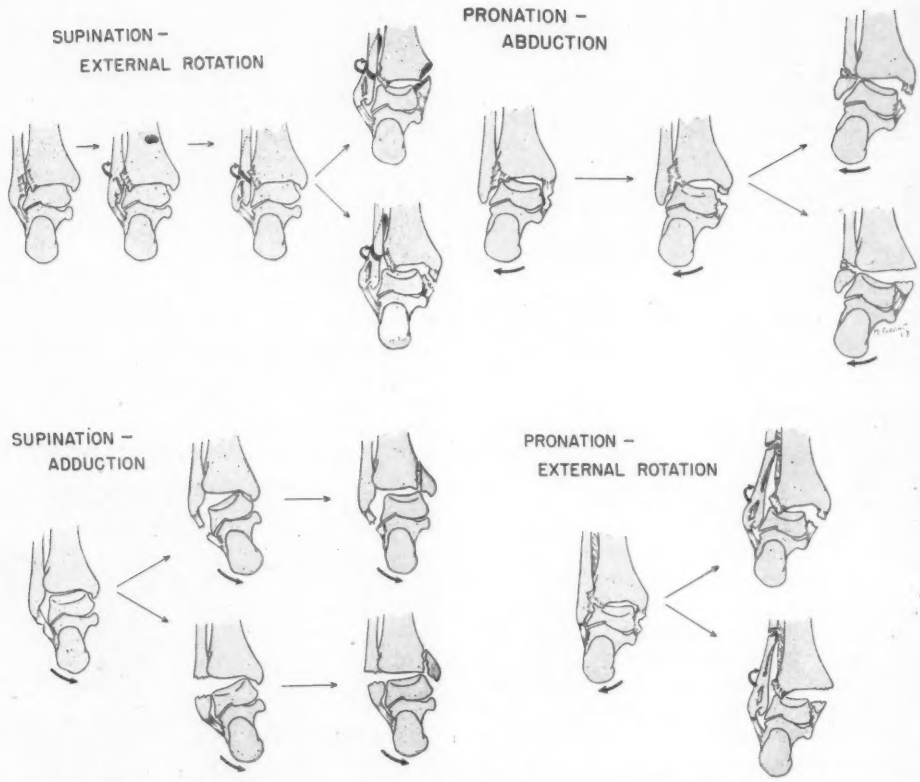

FIG. 2. Common patterns of injury to the ankles, showing effect of increasing force. (From: QUIGLEY, T. B. Management of ankle injuries sustained in sports. *J. A. M. A.*, 169: 1431–1436, 1959.)

DIAGNOSIS

Much more can be learned from the history of the injury in the athlete than from accidents occurring under ordinary circumstances. This is particularly true if the doctor knows something of the maneuvers and procedures of the sport. If he can actually see the injury occur, as he should if the sport is an organized game, he has a tremendous advantage in its analysis.

The immediate examination must be thorough, orderly and complete. Roentgenograms are almost absolutely essential. It is better to take fifty negative roentgenograms than to miss one fracture.

The pattern of injury, the location of tenderness and the type of fracture, if present, should make it possible to determine within a very few minutes whether the injury is major, involving fracture or ligament rupture, or both; or minor, consisting of sprain or partial ligament rupture.

Most injuries to the ankle in general, and certainly the great majority of those occurring in athletics, are the result of the play of three forces on three ligaments and three bones. The forces are (1) supination (or pronation), (2) abduction (or adduction), and (3) external (or internal) rotation. The ligaments are (1) the fibular collateral, (2) the deltoid and (3) the tibiofibular ligaments. (Fig. 2.) This scheme may well be an oversimplification, but when the types of malleolar fracture produced by combinations of these forces are examined, it will be found, as Lauge-Hansen [3] has pointed out, that they constitute a most valuable key to the existence of concomitant ligament rupture which might otherwise be unsuspected. (Fig. 3.)

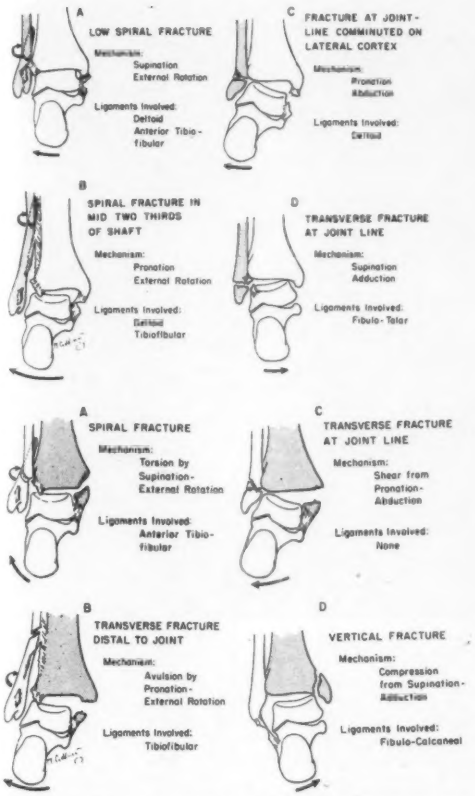

FIG. 3. Fracture patterns in the fibula and medial malleolus which are reliable keys to concomitant injury to the ligaments. (From: QUIGLEY, T. B. Management of ankle injuries sustained in sports. *J. A. M. A.*, 169: 1431–1436, 1959.)

In case of doubt regarding the integrity of ligaments, advantage can be taken of the fifteen to twenty minutes of analgesia imposed by nature after injury, to settle the matter by anteroposterior roentgenograms taken in inversion or eversion stress. Later, when edema, muscle spasm and pain have become established an anesthetic may be required. (Figs. 4 and 5.)

At the primary examination, then, the injury is established as *major* or *minor* and appropriate treatment can begin at once.

TREATMENT

Fractures must be reduced, the sooner the better. Again, advantage can be taken of the analgesic period following injury. Little less

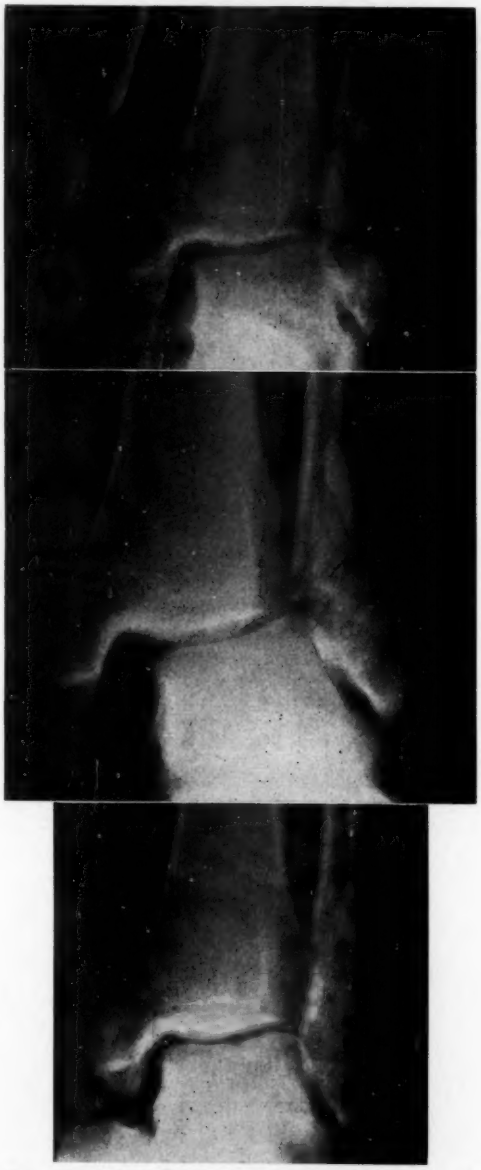

FIG. 4. *Top*, supination-external rotation fracture of distal fibula sustained in skiing two days after injury. Forces of injury, pattern of fibula fracture, and slight widening of space between talus and medial malleolus make rupture of deltoid ligament a virtual certainty. *Middle*, under anesthesia, stresses producing the injury are reproduced, and rupture of deltoid ligament is clearly demonstrated. *Bottom*, after suture of torn deltoid ligament and adjacent anterior joint capsule, normal relationships are restored.

FIG. 5. Supination-adduction stress, reproducing the original injury, demonstrates rupture of the fibular collateral ligament.

FIG. 6. An unhappy result of incorrect analysis and misguided treatment of a pronation-external rotation injury sustained in skiing. The torn deltoid ligament was not recognized and has calcified in its trapped position between the talus and medial malleolus. The added trauma of screw fixation of the fibula probably contributed to the cross union. Dorsiflexion is limited to 85 degrees and pain accompanies all but the lightest activity. Further surgery was refused.

than anatomic perfection can be accepted in individuals vigorous enough to be injured in athletics. Contraindications to surgery, such as poor vascular supply, skin lesions and other conditions associated with age and degeneration, are practically non-existent in this type of patient, and there should be no hesitation in carrying out open reduction of fractures and suture of torn ligaments when necessary. A perfect reduction in the postmanipulation x-ray films does not necessarily mean perfect apposition of rupture ligaments. The philosophy of prompt suture of ruptured ligaments at the knee has been well established [*4–6*]. The same should hold true for the ankle. Clinical evidence that precise surgical restoration is much to be preferred to blind immobilization and hope has recently been supported by the laboratory studies of Clayton and Weir [*7*] published elsewhere in this issue. Failure to recognize concomitant injury to the ligaments in the presence of fracture can produce appreciable disability. (Figs. 6 and 7.)

The most frequent contraindication to immediate surgical fixation of fractures and suture of ligaments when indicated is edema. Compression, elevation and splinting after primary reduction will almost always make definitive surgery possible within a few days. For the common abduction-external rotation patterns of injury the simple suspension of the stockinette encased limb is most useful. When the gastrocnemius muscle is relaxed by flexion of the knee, the ankle and foot naturally fall into adduction, moderate flexion and supination, reversing the mechanism of injury [*8*]. Edema subsides rapidly from the elevation and gentle compression of the stockinette, posterior subluxation of the talus (if present) is corrected, and often an excellent reduction as seen on x-ray films is achieved. Enough

7A 7B 7C

FIG. 7. An unrecognized rupture of the deltoid ligament. A, a healed abduction-external rotation skating injury two years after treatment with a walking boot for five weeks. The distal fibula and talus are displaced laterally. Pain accompanies any activity. *B*, the torn deltoid ligament has been dissected out of the joint and reconstructed. The fracture of the fibula has been recreated by osteotomy and the joint mortise restored with a bolt which was removed three months later. C, two years after operation. The range of motion is normal, but pain follows any unusual exertion.

medial malleolus must be intact, of course, to prevent the talus from displacing medially.

After closed reduction or operation, the ankle in most major ankle injuries should be immobilized for at least four to six weeks in a cast extending from the toes to the groin with enough flexion at the knee to prevent rotation of the tibia and fibula. There is no advantage and considerable risk in the use of the plaster of paris walking boot for any but the simplest injuries of bone and ligament of the ankle [9]. Torsion within a walking boot can displace even the common and usually uncomplicated external rotation fractures of the distal fibula since concomitant injury to the deltoid ligament can be more severe than originally appreciated.

If, at the first examination, within moments of injury, the damage is found to be *minor*, four principles of treatment are instituted—(1) application of cold, (2) compression, (3) rest and (4) elevation. These are based on the concept that a sprain is a partial tear of a ligament, with hemorrhage at the point of tear, absorption of the resulting hematoma, and replacement of the gap by fibroblastic scar [2]. The process is the same as the healing of any sterile wound. No method has yet been found to accelerate healing beyond nature's rate, but many are available which slow it down or disturb the end result [10]. Among these are the use of procaine hydrochloride (Novocain®), hydrocortisone, rough manipulation and massage, and "running it out." *Cold* promptly applied, constricts the arteriolar bed and limits the hematoma. *Compression* disseminates the hematoma already present and speeds its absorption by increasing its surface area. (Fig. 8.) *Rest* is obvious. As in any injury, whatever is painful, is wrong; whatever does not hurt, is right. *Elevation* minimizes the edema of dependency and disuse.

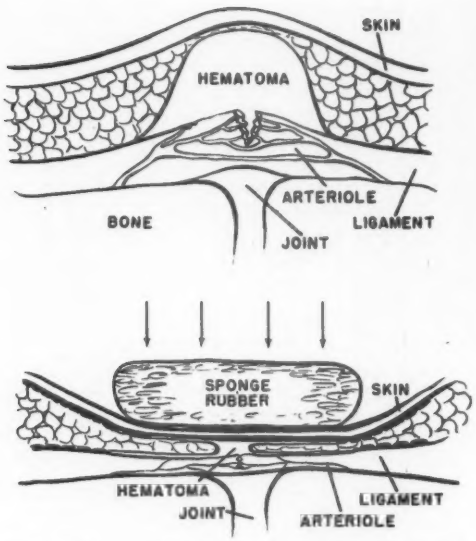

FIG. 8. Compression disseminates the hematoma of sprain, increasing its surface area, speeding absorption, and minimizing scar. (From: QUIGLEY, T. B. Management of ankle injuries sustained in sports. *J. A. M. A.*, 169: 1431–1436, 1959.)

At the first examination, when injury has been determined to be a sprain and not a fracture or ligament rupture, a bevelled doughnut of foam rubber, 2.0 cm. in thickness, is placed over the injured side of the ankle with the malleolus in the aperture. The skin is protected from direct contact with the rubber by sheet wadding. The rubber is then compressed to about half its thickness with an elastic cotton bandage, extending from the toes to the upper calf. (Fig. 9.) The limb is then immersed in cold water (40 degrees) or packed in ice bags for thirty minutes. The wet dressing is then replaced, crutches are fitted, and the patient instructed in their use. He is advised to spend as much time as possible during the next twenty-four hours with the ankle elevated above the level of the heart.

At the second examination (the next day), edema should be minimal, ecchymosis may already have appeared at the periphery of the foam rubber pad, and by gentle palpation and manipulation an accurate analysis of the particular ligaments involved and their degree of involvement can be made. (Fig. 10.) It is convenient to grade the severity of sprain from 1 to 4, 1 being the least degree of injury which

FIG. 9. Foam rubber and elastic compression for sprain of the anterior tibiofibular and fibular collateral ligament.

can be classified as sprain, and 4, complete rupture. Such classification is of help in prognosis, a matter of great importance to most athletes. The majority of sprains fall into grades 2 and 3. Experience during the past seventy years at the Harvard department of athletics has established that the most frequent injury to the ankle, a grade 2 sprain of the anterior tibiofibular and fibulotalar ligaments, treated properly, with full cooperation from the patient-player, will be sufficiently healed in 8.2 days to permit full participation

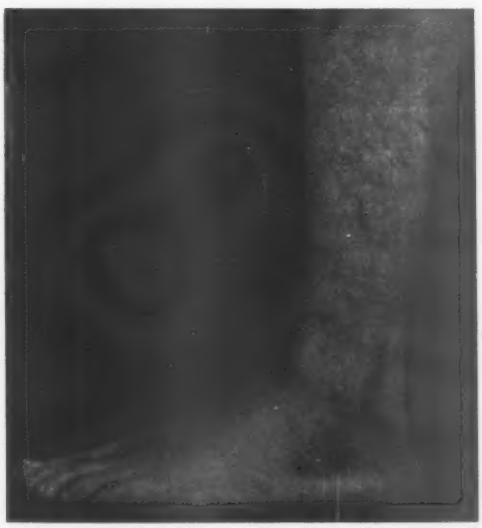

FIG. 10. The effect of compression on a typical sprain of the anterior tibiofibular ligament of the ankle. Ecchymosis is seen at the periphery of the compression bandage. Edema is minimal.

in contact sport. It has become equally clear over these seven decades that any prognosis ventured before the second examination, twenty-four hours after injury, is almost certain to be wrong.

At this second visit, it can safely be assumed that the sources of bleeding have sealed off, and heat therapy, followed by gentle centripedal massage, can be started. Electronic and other complicated sources of heat have little advantage over hot water. Diathermy, in fact, is contraindicated in injuries to the joints since it tends to produce effusion. The psychologic effect of a whirlpool bath is much greater than the massage of moving water and bubbles.

Weight bearing is permitted as soon as natural walking is possible. When pain and tenderness approach the vanishing point, the ankle is taped. Return to full activity is safe only if performance is flawless. For vigorous sport the ankle should be protected by adhesive tape with turns around the heel to minimize lateral mobility for at least the next year. The old adage "once a sprain, always a sprain" has sound basis in the fact that ligament heals with scar, which is only slowly replaced by orderly elastic collagenous tissue, and the disorganized fibroblast pattern of scar is always weaker than the tissue it replaces.

There is no justification whatever for the use of procaine in any athletic injury except occasionaly as a diagnostic measure, for stress studies to determine the presence or absence of ligament rupture. Pain may temporarily be abolished, but performance is usually poor and further damage to the injured structure is almost inevitable. Hyaluronidase and hydrocortisone occasionally may have a place when hemorrhage is unusual in degree, or sensitivity to pain high and there is no doubt that the injured ligament is intact.

Plaster splints are used only for severe or multiple sprains, and are removed as soon as possible. Atrophy of thigh and calf musculature can occur at a remarkable rate and can be corrected only by careful, daily, supervised, progressive resistance exercise [*11*].

SUMMARY

A program of prevention, prompt diagnosis and treatment of injuries to the ankle is presented, including methods of demonstration of complete ligament rupture or avulsion.

Precise surgical repair of completely torn supporting soft tissues is rarely contraindicated in athletes, and little less than perfect reduction of fractures is acceptable.

Sprains, or incomplete ligament tears are best treated immediately by cold, compression, rest and elevation.

No way has been found to accelerate the healing of a wound, such as a sprain, but many things can delay the process including novocain, hydrocortisone, manipulation and "running it out."

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Elbow and Shoulder Lesions of Baseball Players

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EIGHTEEN years have elapsed since my first article on elbow and shoulder disabilities of ball players was published [1] and as I read it I find I have not changed my opinion as to diagnosis, clinical findings and treatment. Since I do not believe I can express my opinions in more lucid terms I shall make a number of direct quotations.

On many occasions I have been asked to designate the type of lesion that is disabling to the professional baseball player. My answer has always been that the baseball player is subject to the same disabilities of the shoulder and elbow as the average person, namely subacromial and subdeltoid bursitis, irritation of the supraspinatus, irritation of the biceps tendon, traumatic synovitis and all the inflammatory diseases. Needless to say, because of his professional activities disability of the shoulder and elbow occurs more frequently in the ball player than in one not engaged in an occupation which requires such excessive physical use of these articulations.

Since professional athletes are human beings, not supermen, general health often plays a part in the disability and should be the first thought in the mind of the medical examiner. Frequently, infected teeth or tonsils cause or aggravate the irritated joints. Lesions of the inflammatory group respond to removal of infection and to an improved general health regimen.

FIG. 1. Osteochrondritis of the olecranon.

ELBOW

Shands [3] proved conclusively that trauma to hyaline cartilage produced a definite hyperplasia. The margins and the tip of the olecranon and the adjacent surfaces of the condyles of the humerus are constantly traumatized by the throwing of a baseball. The result produces a definite osteochondritis with exfoliation of cartilage which may produce loose bodies, synovial thickening or semiattached cartilagenous masses which obstruct and limit the extension of the elbow. This is the most common lesion seen in baseball players. (Figs. 1 and 2.) In the presence of pain, swelling and disability which is prolonged, the lesions respond well to removal. If the lipping of the cartilage of the olecranon and the condyles is marked, these structures can be removed. In many instances this lesion exists without symp-

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FIG. 2. Osteochrondritis of the olecranon and loose bodies.

toms, or only intermittent transient discomfort, and should not be removed.

Olecranon Fractures. Fractures of the olecranon are not frequent. I recall only four instances, two of which occurred in young athletes, and both happened in batting. The weight of the bat assisted in extending the elbow to such a degree that a small chip fracture resulted. Operation and removal of the detached piece of bone gave prompt relief. (Fig. 3.)

FIG. 3. Chip fracture of the olecranon from batting.

The third case was a rather unusual fracture which occurred when a player, whose normal position was first base, was assigned to the outfield. When making the long hard throw, he had sudden pain and immediate disability. (Fig. 4.) Roentgenographic examination disclosed that the fracture was due to a marked deformity and elongation of the olecranon, probably the result of an injury in childhood. The fracture was wired and the player returned to active play. It was believed that his ole-

4 5

FIG. 4. Deformity of the olecranon predisposing fracture from throwing a baseball.

FIG. 5. Fatigue fracture of the olecranon.

FIG. 6. Small spur formation of the internal condyle of the ulna.

FIG. 7. Progressive development of spur.

FIG. 8. Large spur of the internal condyle of the ulna.

FIG. 9. Large spur with ossicle.

cranon would fracture again unless the elongated and deformed tip was removed. My associate (Dr. E. McDonnell) removed a generous portion of the olecranon and reattached the triceps. The player states that his arm is stronger and that he can throw harder than at any time in the past. He is one of the best first basemen in the American League.

The fourth case is a curious one. I must theorize as to the etiology and have made no definite plan as to treatment except to await results. I have advised rest. In this young catcher, without history of trauma, the elbow of his throwing arm gradually became painful. Roentgenographic examination disclosed a pathologic condition which to me is similar to fatigue or march fracture in the foot. (Fig. 5.)

Spurs. A sharpening and spur formation of the articulation between the internal condyle of the humerus and the ulna is frequent and

often transient. At times, however, it is necessary to remove the spurs in rather young ball players.

It is curious how closely these spurs present the same clinical picture that is seen in spurs of the os calcis. Very often these spurs are so small that they are difficult to visualize in the x-ray film. However, they are extremely painful.

In contrast to this, one often sees very large exostoses which are painless. Two examples are demonstrated in Figures 6 and 7. The left-handed pitcher in Figure 8 consulted me regarding a definite shoulder lesion. He also presented the common loss of extension of the elbow. Routine roentgenogram demonstrated the huge exostosis which was symptomless; surgery was not performed.

The second case was that of a veteran pitcher in whom a progressive disability had developed and who, for the past year, was unable to throw a baseball hard. It is quite obvious that this exostosis took years to develop. Surgery was performed and he had several active years in baseball. (Fig. 9.) One can see the progressive development of these exostoses in Figures 6 through 9.

There is a lesion which produces a different syndrome. A pitcher in throwing a curve ball is compelled to supinate his wrist with a snap at the end of his delivery. This movement plus extension leads to the development of an irritation in front of and below the internal condyle of the humerus which is extremely disabling. On examination one will note distinct fullness over the pronator radii teres, beneath which are the tendinous attachments of the brachialis and the flexor sublimis digitorum. These are covered by a strong fascial band, a portion of which is the attachment of the biceps, which runs obliquely across the pronator muscle. A pitcher may be able to pitch for two or three innings but then the pain and swelling become so great that he has to retire. Roentgenograms in the majority of cases are entirely within normal limits, and my experience shows that exploration of the joint reveals no pathology and, therefore, is not advised. The muscle tissue generally is normal in appearance. A simple linear and transverse division of the fascia covering the muscles has relieved tension on many occasions and rehabilitated these men so that they were able to return to the game. I am at a loss to explain it except that tension develops

FIG. 10. Ossicle in the ligamentous tissue.

from some unidentified irritation to the muscle tissue, or it is quite possible that this may be secondary to an irritation of the ulna at its articulation with the internal condyle.

Deposits of Bone or Ossicles. A distinctive lesion, and one which is not seen in other occupations, is the development of single or multiple deposits of bone or ossicles in the ligamentous tissue and tendinous attachments beneath the ulnar nerve and not within the joint. I am quite sure that these deposits are purely the result of chronic strain and probably take years to develop. In many instances there are no symptoms. When these deposits cause irritation of the ulnar nerve they can be removed with success. Identifying these small masses of bone in the ligamentous tissue, and dissecting them free, will relieve symptoms in most cases. On exposure of the joint, care must be taken to avoid injury to the ulnar nerve. As a rule there is nothing to be seen or palpated; however, the ossicles can be located by the use of a long skin needle puncturing the ligamentous tissue and locating the osseous mass. It can then be dissected free. I never attempt to close the hiatus in the ligamentous tissue [2]. (Fig. 10.)

SHOULDER

For many years I have been able to demonstrate a lesion in the shoulder of professional pitchers and other baseball players which I do not think one sees in other persons. Because of the excessive use of the arm and the tremendous pull on the posterior capsule and the triceps

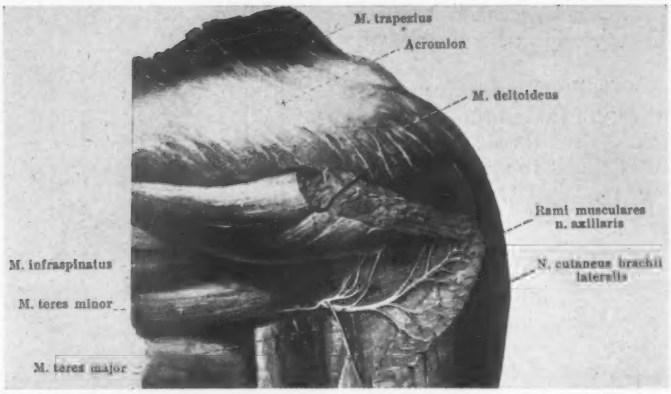


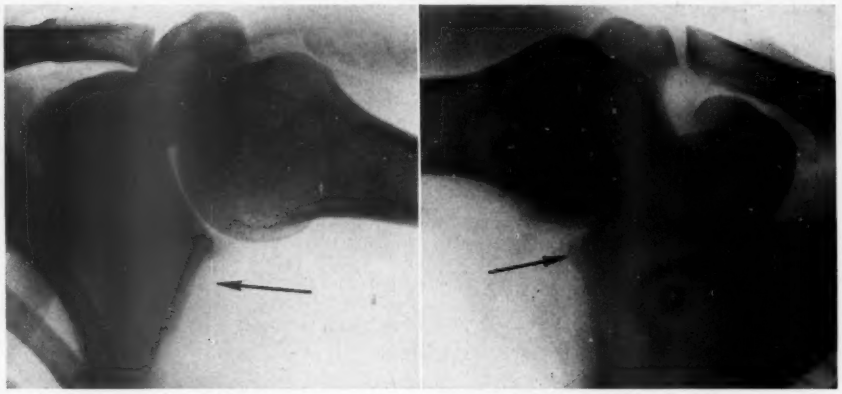
FIG. 11. Circumflex nerve in proximity to exostosis. (From: SPALTEHOLZ, W. Hand Atlas of Human Anatomy, vol. 3, p. 760. Philadelphia, 1923. J. B. Lippincott Co.

tendon, a deposit of bone develops on the posterior inferior border of the glenoid fossa which is strikingly similar to the osteoarthritic deposit that one sees in older people. The location of this deposit is such that it produces an irritation of the capsule and of the synovial membrane. This exostosis or deposit also produces an irritation of the circumflex nerve with referred pain to the deltoid region. (Fig. 11.) The symptoms are local discomfort and sensitiveness on palpation in the posterior shoulder plus referred pain to the deltoid region. When the player attempts to throw hard after one or two innings, he suffers so much pain and discomfort that he is unable to continue in the game.

Careful observation of the position of the arm and the arc of motion helps to prove the cause of disability. On observing a professional pitcher as he "warms up," throwing a ball easily while he gradually increases its speed, one will notice that when he begins to "stretch" he seems to be trying to throw his arm at the catcher. After the warm up, he reports that his arm is "loose" and feels fine. This statement is true, because to be effective his arm must be relaxed at the finish of the delivery. When the arm is "tight" the muscles are spastic and effectiveness is lost. One does not have to draw on the imagination to appreciate the tremendous pull on the posterior and anterior shoulder as the weight of the arm is swished forward in a flail-like motion. This constant strain tends to cause the development of a pathologic process in the posterior and inferior margin of the glenoid fossa which is strikingly similar to the formation of exostosis in other joints that have been subjected to excessive strain and overuse. Fortunately, this is not a constant disability of the "veteran." I have examined professional pitchers who, after twenty years of active baseball life, show no such deposits, on the other hand I have seen youngsters of twenty or twenty-one years in whom these same changes have already occurred. Symptoms may develop gradually with an increase in severity or may have a sudden onset. The pitcher may be able to tell the pitch and the day when he suffered this sudden pain in the back of his shoulder. The pain persists and he can throw "hard" only a few innings, then the local posterior pain plus the referred pain to the deltoid region becomes so great that his arm feels "dead."

It is a common observation that deposits in other joints may exist for a considerable time, causing no inconvenience. For instance, when a sneeze is said to produce an attack of lumbago, the roentgenogram may show deposits on the vertebrae which have been developing for years. I do not believe one can say that a sudden strain is responsible for the lesion I am attempting to describe. (Figs. 12 and 13.)

The treatment of the exostosis or deposits in this part of the shoulder is difficult, and it is distinctive of the baseball player. It causes no pain or discomfort for normal function of the shoulder, not even in throwing a baseball at moderate speed. Symptoms are produced only when the baseball is thrown hard. Therefore, it



12 13

FIGS. 12 and 13. Exostosis of the inferior border of glenoid.

is not a question of having the shoulder perform a normal function but of rehabilitating it to perform again the abnormal function that produced the pathologic process. (Fig. 14.) My experience is that operative treatment is not satisfactory and, therefore, not advised.

Bursitis. Acute traumatic bursitis is a common complaint which responds well to rest and local heat.

Calcium deposits in the bursae and the supraspinatus tendon are not common. I can recall only one instance of a deposit of long

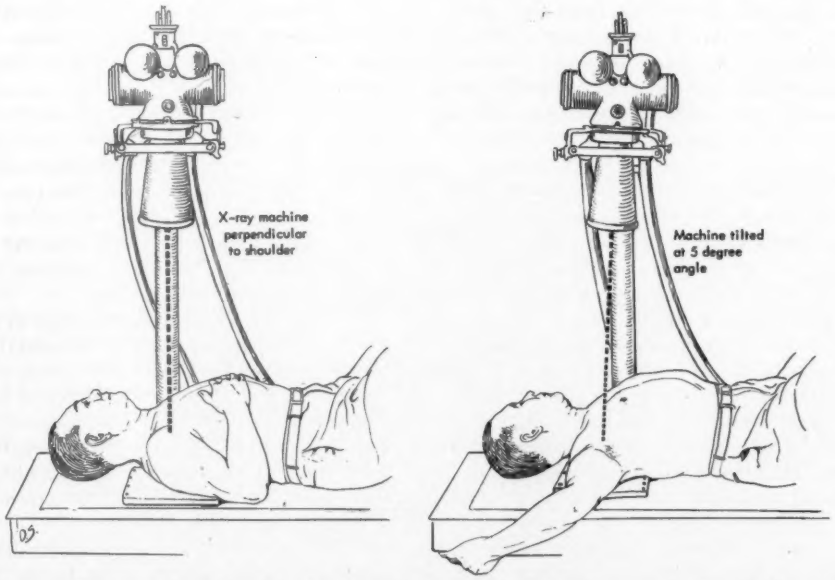


FIG. 14. The exostosis or deposit in the posteroinferior region of glenoid cannot be identified by the ordinary anteroposterior or posteroanterior view of the shoulder. I am grateful to our x-ray technician Mr. W. Ross Mitchell, for development of the technic shown. External rotation of the humerus with tilting of the x-ray tube about 5 degrees is the position which rotates the head of the humerus and the glenoid to a position which throws the thickened area in relief. (From: BENNETT, G. E. [1].)

FIG. 15. Acute traumatic separation of the supraspinatus tendon.

FIG. 16. Chronic fraying of the supraspinatus with rupture of the tendon.

duration which required operation. The patient made a complete recovery and he continued to be an effective pitcher.

Chronic traumatic bursitis with a thickening of the subacromial bursa has been observed on numerous occasions. The symptoms are local discomfort and at times crepitus. This is a disabling lesion which does not respond to local or operative treatment. I have explored this type of shoulder against my better judgment at the request of patients who pleaded for an operation, and have found a thickened membrane with rugae. A complete excision has not been successful in restoring function.

Fraying of the Tendon. The supraspinatus tendon is subject to great strain and snubbing by the head of the humerus, as a result fraying of the tendon occurs in proximity to the head of the humerus and the tuberosity. It is a lesion which is seen most often in the veteran pitcher and is characterized by pain in the region of the tuberosity and the anterior shoulder. I have explored this type of lesion at the request of patients to find a smooth superior surface of the tendon, but upon making a linear incision of the tendon, a fraying of the deep structure is revealed. This, also, is a pathologic process which does not respond to surgical or other treatment.

Tearing of the supraspinatus is rare. I am reporting two such cases in detail. In one case the player was injured when he slid into second base and grasped the bag with his pitching arm. On exploration it was found that a small portion of the tendon was pulled from the tuberosity and created a mass. (Fig. 15.) Excision of this mass of macerated tendon and the suturing of the tendon produced a very satisfactory result. The patient, who was twenty-seven years of age, was able to pitch effectively for several years afterward.

The second case was that of a thirty-four year old player who had pitched in the minor leagues since he was eighteen years of age, and in the National League for eight years. His description of his symptoms indicated that for a considerable time he had had pain similar to that caused by a frayed tendon. One year prior to his visit to me in 1948, he had thrown a baseball hard and had had a sensation of a snap in his shoulder with intense pain. He had not been able to pitch since. The operative findings were as I had suspected, a frayed tendon which had suddenly torn. The result was obvious. I repaired the torn portion but could not repair the fraying of the deep surface of the tendon. He had worn out the tendon, and was never able to return to the mound. (Fig. 16.)

It will be noted that the x-ray findings are almost identical in these cases. In the first case the lesion was traumatic and in a younger man; the result was satisfactory. In the second case the patient was a veteran who had worn out his supraspinatus tendon; the result, as could be expected, was a failure so far as his being

able to continue as a ball player but satisfactory for normal function.

The biceps tendon is a structure which at times presents symptoms but not as frequently as the supraspinatus or the infraspinatus tendons. At times it becomes frayed. Also, it may become partially dislocated. One patient with this complaint consulted me and presented the typical syndrome which has been described by DePalma [4]. The player had no pain when throwing a baseball, only when batting. As this player resided in Philadelphia, I referred him to Dr. DePalma who operated, found a partially displaced tendon and performed a fixation via his stapling procedure. The result was satisfactory and the player was able to return to active play.

Loose Bodies. Loose bodies in the shoulder joint are rare. I can recall one college shortstop who complained of intermittent catching and swelling of the shoulder. I operated, exploring through the axilla, and removed the loose body with a very satisfactory result. (Fig. 17.)

FIG. 17. Loose body in the shoulder joint.

SCAPULA

Players, particularly pitchers, often complain of marked discomfort in the region of the infraspinatus muscle. This may be caused by simple myositis and may be transient. Dr. George Resta of Washington is of the impression that it also may be due to an irritation of the suprascapular nerve. A glance at Figure 18 makes this deduction rational. The suprascapular nerve supplies the supraspinatus, the infraspinatus and to a lesser extent the posterior shoulder. If one considers the excursion of the scapula forward in the throwing of a baseball, it seems quite possible that this nerve could be irritated as it passes beneath the base of the acromion where it joins the spine of the scapula.

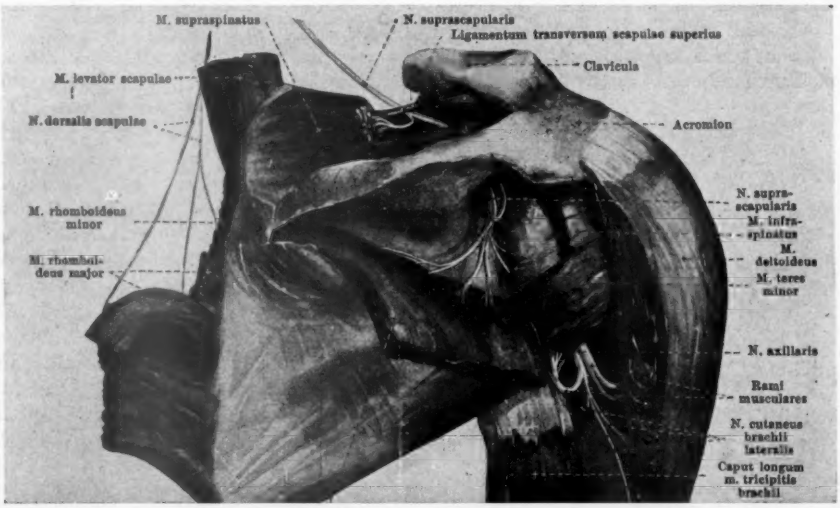


FIG. 18. Demonstrating the location of the suprascapular nerve (From: SPALTEHOLTZ, W. Hand Atlas of Human Anatomy, vol. 3, p. 746. Philadelphia, 1923. J. B. Lippincott Co.)

I have requested Dr. Resta to describe his method of treatment, which follows:

"As you already know, I have been injecting the suprascapular nerve since 1947. The technique I employ is to lay the individual face down, with the extremity elevated, the point of insertion being beneath the acromion at an oblique angle, a 22 gauge, three inch needle being used. Upon contact of the nerve, the patient experiences pain. This is usually encountered following the insertion of the needle to about two inches.

"From 1947 to 1952 Novocaine was used; from 1952 to date, steroids (Hydrocortone 50 mg. per cc. employed by me) were used. Usually one, never more than two cubic centimeters of Hydrocortone were used. I have found one injection to be sufficient.

"The post-injection therapy is simple. The individual is instructed to use the arm to full capacity the following day.

"I have treated thirty-two baseball players since 1947."

The injection of anesthetics into trigger points of painful spastic muscles is an old treatment which is often successful.

In conclusion, I take this opportunity to make a statement that may be questioned. It is my opinion that the throwing of a baseball side arm produces less trauma to the vulnerable superior and anterior structures of the shoulder than the throwing of a baseball by so-called overhand delivery.

The overhand delivery snubs the supraspinatus more than the side arm delivery. With the latter method the head of the humerus glides laterally and not in the semi-perpendicular position.

It is a very definite fact that veteran pitchers gradually lower the delivery from overhand to three-quarters and then side arm. The reason must be comfort. When this statement is made to a manager or coach he will remark that a baseball cannot be thrown as hard from side arm as from overhand. Nevertheless, the fastest pitcher in the game is reported to have been Walter Johnson, who was strictly a side arm pitcher.

On many occasions I have suggested this type of delivery to pitchers who have had the supraspinatus syndrome, with satisfactory results.

I cannot mention names but a few years past an overhand pitcher consulted me. When I asked him if he had pain in the shoulder when he used a side arm delivery, he answered that he did not. My statement to him was: "You are now a side arm pitcher." The result was that he pitched successfully for several years, occasionally making an overhand delivery.

The side arm delivery does not lessen the pull on the posterior shoulder.

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Ski Injuries

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WHENEVER man attempts to move at a rapid rate of speed, over an irregular terrain, among rocks and trees, he is apt to get hurt. This is downhill skiing. The circumstances mentioned are sufficient to account for all types of trauma. The skier, however, compounds his vulnerability to injury by fixing to his feet an extended lever arm several feet long. This lever arm, when twisted, acts on a fulcrum represented by the tibiofibular joint. The forces exerted at this point may be transmitted to the entire lower extremity.

As a recreational sport, skiing had its beginning in the latter part of the last century. From a simple means of transportation, skis became a means for touring in the mountains and it was inevitable that the thrill of a downhill run would be experienced. The use of skis in sliding down a hill required modifications in the boot-ski relationships. Loose attachments of boot to ski, and a trailing pole to control course, as a rudder guides a ship, had to be improved upon. In 1928 the first diagonal pull cable binding was developed. Subsequent developments in bindings and boots created a situation in which the foot and the ski functioned as a single unit. Thus, these factors which popularized the sport made it dangerous.

In the memories of many veteran skiers, the sport of skiing has developed from a few thousand enthusiasts to include millions. It has been estimated that skiing now is second only to fishing as a participating sport. The development of various snow areas, the change in vacation patterns, the economic factors which deal with manufacture and sale of equipment, have assumed proportions which invite understanding and study of all of the facets of this sport.

STATISTICS OF INJURY

Accuracy in any statistical study of ski injuries, requires a situation in which correct figures are available as to the numbers of skiers each day and the number of injuries occurring. The operation of ski facilities at Sun Valley [*10*] make the former possible, for ski lifts and bus rides to the lifts are recorded. The isolation of the area and the organization of the medical facilities provide, as nearly as it is possible, for the completeness of injury count and classification. All injured persons who require ski patrol aid, are brought to a central point for processing. There are, without doubt, persons with injuries of a minor nature leaving the area and thus not accounted for but these are probably negligible in number.

In any given skiing holiday of two weeks' duration, 10 per cent of the skiing group will report an injury due to skiing. This has been established repeatedly by a review of the records of small groups. A ski season which includes 100 days of skiing has been studied. (Table I.) During this period, over 80,000 ski days occurred, representing an average of 800 skiers per day. These figures, of course, include all skiers from beginners to experts, those in class and those skiing independently. They also represent injuries which occur under all variations of snow conditions and on all types of slopes.

The skiing injuries which occurred over a 500-day period at Sun Valley, have also been classified. During this period, 2,578 injuries were reported. (Table II.) Every type of physical trauma is represented in this group. The injuries which result from the lever arm action

TABLE I
INCIDENCE OF INJURIES RELATED TO SKIING DAYS

Any reportable injury	1 per 137 days
Ankle sprain	1 per 600 days
Knee sprain	1 per 788 days
Fracture (all types)	1 per 825 days
Fracture (distal fibular head)	1 per 1,576 days
Fracture (tibia and fibula)	1 per 4,335 days

TABLE II
SKI INJURIES IN 500-DAY PERIOD

Torsion strain injuries		1,874
Sprains	1,496	
Fractures	378	
All others		704
Total		2,578

TABLE III
TORSIONAL STRAIN INJURIES OF LOWER EXTREMITIES

Ankle sprains	783
Knee sprains	601
Ankle fractures	280
Tarsal sprains	110
Tibia-fibula shaft fractures	80
Metatarsal fractures	8
Miscellaneous	12

of the attached ski, are slightly over 70 per cent of the total. Table III gives a tabulation of this 70 per cent group and it shows the distribution of injuries numerically. Since it is not the purpose of this paper to discuss the general subject of trauma, attention will be limited to this 70 per cent group, and the title might be stated more accurately by the name "torsional strain injuries of the lower extremities."

ANKLE SPRAINS

An ankle sprain [5] is "a partial or complete tear or a stretching of one or more ligaments about the joint, caused by a sudden twisting or wrenching of the bones which constitute that joint" [11]. This injury may be a minor one as described by Leriche [6] or one in which the joint is rendered completely unstable [3].

The fulcrum upon which the ski lever arm exerts its force is the tibiofibular joint. Therefore, it follows, that injury should occur to this structure or to the ligamentous attachments. There are, however, modifications of the force and of the speed with which it is applied; therefore, the pathology of ski sprains is varied. The logical approach to the treatment of sprains is accurate diagnosis. Early examination after the sprain occurs, gives the examiner a great advantage. At this time there is minimal pain and minimal swelling. Manipulation may be made with the least subjective complaint. We believe the routine examination at this time should include the following steps:

1. A history is obtained of the mechanism of the injury as nearly as the patient can remember what happened.

2. The ankle is inspected for deformity and swelling.

3. The Achilles tendon is palpated to evaluate its continuity.

4. The foot is passively plantar-flexed and an attempt made to dislocate the peroneal tendons, thus ascertaining whether or not the retinaculum has been torn.

5. The foot is inverted and if an abnormal degree of tilting of the talus results, an attempt should be made to palpate the fibulocalcaneal ligament. Since there is great variation in the mobility of ankles, the uninjured ankle should be examined also for comparison.

6. The foot is everted and the deltoid ligament palpated.

7. An attempt is made to identify the posterior tibial tendon relative to its normal position by actively everting the foot. Lancinate ligament tears will permit anterior displacement of this tendon.

8. The foot is externally rotated and an x-ray film taken in the anteroposterior plane. Tearing of the anterior inferior tibiofibular ligament will permit diastasis. This will be recognized by a shift of the talus laterally, thus revealing a widened space between the medial malleolus and talus. Also, this film may show an actual shift of the fibular head laterally. Normally, the posterolateral ridge of the tibia overlies half or more of the shadow made by the fibular head in the true anteroposterior plane.

It is a frequent experience to see an ankle sprain several hours after it has occurred and after the skier has soaked it in hot water. The entire joint is then swollen and painful. Examination and evaluation of the injury at this time is more difficult. Because of the pain and swelling, an examination to determine stability, as already outlined, may require the use of either local or even general anesthesia. Having completed this routine examination, the surgeon will have formed an opinion as to whether the tearing of supporting structures is partial or complete; that is, whether the stability of the ankle joint has been impaired or not. The question of the degree of tear is still undetermined. Where there has been partial tear, treatment is controversial. We believe that all ankle sprains, even with a stable joint, should be treated conservatively and as serious injuries until proved otherwise. The methods advocated by Thorn-

dyke [12] are effective. There should be immediate control of hemorrhage and the subsequent hematoma formation. Cold immersion for at least twenty minutes, followed by the application of sponge rubber compression and no weight bearing is an acceptable means of accomplishing this purpose. Even in a matter of hours, distention of the joint may occur. This distention may be very painful, and aspiration, followed by injection of hyaluronidase or hydrocortisone, will aid in reducing viscosity and thus permit reabsorption. The distended joint capsule conceivably alters capillary and lymphatic function of synovial fluid absorption and unless this cycle of increased effusion and decreased absorption is broken, recovery will be delayed [4]. The continued use of compression hastens absorption of the hematoma by providing a continuous, gentle massaging action. Pain is an excellent guide to follow-up treatment. After forty-eight hours, during which time compression has been applied and weight-bearing prohibited, hydrotherapy, ultrasonic treatment and active exercises are beneficial.

One of the most difficult aspects of treatment of sprains in the skier is to prevent him from a too early return to skiing. Evaluation of the injury on the second day should reveal changes which may permit the surgeon to advise the patient in regard to the probable length of his disability. If the swelling is diffuse, motion limited and weight-bearing painful, it is advisable at this time to state that disability will extend for a period of eight or ten days and that it will not be advisable to resume normal activity for that period of time. His return to skiing when the pain and swelling has subsided, should be permitted only with properly applied adhesive support.

KNEE SPRAINS

This may be the only injury resulting from the torsional force but in 25 per cent of our cases, knee sprain occurred with ankle sprain. It is thought that in the isolated case of knee sprain, two factors may be involved. When the foot and ankle are supported by well fitting boots with interlacings, and when the torsional force is applied slowly, the transmission of this force may bypass the ankle to the knee joint. Sprain of the knee joint occurring from external rotation, usually is represented by injury to the tibial collateral ligament. If examination of the injured knee joint is made within an hour or two after injury, an accurate diagnosis will be extremely difficult to make. Examination at this time will yield some information. The range of motion and the stability of the knee joint can be evaluated. Beyond this, little can be learned.

All sprains of the knee must be treated conservatively. If this early examination reveals a full range of motion and a stable joint, sponge rubber compression is applied over the medial and lateral aspects of the knee joint and the patient is advised to use crutches until seen twenty-four hours later. After twenty-four hours, the knee joint is again examined. Tenderness then may be localized over the medial collateral ligament at joint level. There may be localized tenderness over the femoral insertion of the ligament indicating avulsion of some of the fibers. It must be kept in mind that this injury, if not properly treated, may result in calcification and disability. Very often the knee joint which appeared to be very normal the day before, is now distended by effusion. We believe that every knee joint showing effusion should be aspirated for diagnostic reasons and for therapy [8]. If the fluid is clear, the effusion may represent physiological response to the strain. If the effusion is bloody, one must assume it is due to a tearing of the synovium and possibly a tearing of the fibrous attachment of the medial meniscus. Immobilization in a plaster cylinder offers the best chance for this type of injury to heal with the structures in normal anatomic relationships. The attitude of many surgeons that an injury to the knee cartilage is irreparable, that healing and normal function cannot be restored unless the cartilage is surgically removed, is not established by fact [9]. There is no absolute way to establish the diagnosis of a tear of the fibrous attachment of the meniscus without looking into the knee joint. Since this is not practical, in the interest of making errors on the safe and conservative side, immobilization should be provided. The aspirated fluid may not only be bloody but may contain fat. If this is true, one must assume that the fatty droplets which float on the aspirated blood come from bone and that a fracture of the tibial plateau has occurred.

Sprains of the knee joint are occasionally represented by a complete tear of the medial collateral ligament. When a test for abduction stability indicates that such a tear has occurred,

FIG. 1. "Skiers fracture" without displacement.

surgical repair is indicated. At the time of operation, of course, the status of the medial meniscus is determined and if it is fractured or dislocated, it should be removed. This procedure is followed by immobilization in a plaster cylinder, during which time active quadriceps exercises are prescribed.

FRACTURES OF THE ANKLE

The words "ski fracture" creates a definite picture in the minds of most skiers. This injury is a simple fracture of the distal head of the fibula, as shown in Figure 1. It will be noted that the fracture line begins anteriorly at the level of the joint and extends in a spiral manner posteriorly and cephalad for a distance of several centimeters. In this instance, the torsional force is sufficient to cause fracture of the bone and then it ceases to act so that the fracture represents the total injury. When the foot is held in a neutral position, the ankle joint is found to be stable and a plaster boot, permitting weight-bearing, is adequate treatment. In Figure 2, it will be noted that the injury has been more severe and there is displacement of the distal fibular head. When this fracture is seen and reduced, it is important to test the stability of the ankle joint while the foot is held in a neutral position. The test is carried out by attempting to displace the foot laterally, and while the stress is applied, a roentgenogram is taken in the anteroposterior plane. If no diastasis can be demonstrated by this test, immobilization in a walking cast is acceptable. In Figure 2, the right hand figure shows the unreduced fracture with displacement of the distal fibular head. Reduction by manipulation is carried out by reproducing the fracturing force and at the same time applying traction. As the foot is returned to a neutral position, the displacement corrects itself. In the left hand panel, the reduced fracture will be seen. The anterior inferior tibiofibular ligament in this instance has not been torn, and as long as the foot is maintained in a neutral position, the ankle joint is stable. Consequently, weight-bearing on the plaster

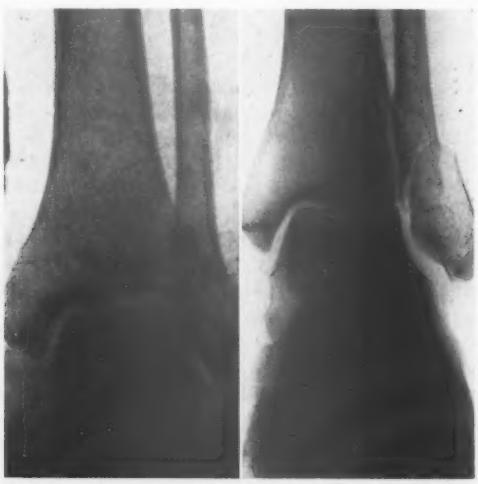

FIG. 2. "Skiers fracture" with displacement of distal fibular head.

FIG. 3. Undisplaced fracture of medial malleolus in the oblique plane.

boot is permissible here. External rotational force frequently produces tearing of the anterior inferior tibiofibular ligament as an initial injury. As the force continues to act, fracture of the fibula at higher levels may occur [*1,5,7*]. It is important to bear this fact in mind when a fracture of the fibula alone is found to be present at any level above the ankle joint. The fracture itself may appear to be of little importance but correct management of the diastasis, if it exists, is mandatory.

Routine x-ray examination of the ankle joint should always include an internal oblique view. Figure 3 illustrates why this is necessary. When the torsion force applied to the ankle joint causes the talus to turn in the joint, pressure is exerted on the medial malleolus. The fracture which may result usually is in an oblique plane and may be without displacement. The usual anteroposterior and lateral views may not reveal the presence of the fracture. By internally rotating the ankle 35 to 40 degrees, the fracture line will be visualized. (Fig. 3.)

If the torsional force is applied suddenly, the inertia factor may cause the injury to be an avulsion of the tibial insertion of the anterior inferior tibiofibular ligament, rather than a tearing of the ligament itself. This incident has been likened to the force which tears a boat from its mooring. A suddenly applied force may pull part of the bow away from the boat, although in fact the bow may offer more resistance than the rope to which it is attached. The same force applied more slowly would cause the rope to yield rather than the bow. If the bone to which the ligament is attached, yields to such a sudden force, the fragment will usually be seen in the x-ray films. (Fig. 4.) In our experience, this fracture cannot be reduced and maintained by closed methods. It is necessary to expose the fracture, reseat the bone fragment and suture it in place. The ankle is then immobilized in a non-weight-bearing boot until bone healing has occurred.

Another type of avulsion fracture which is

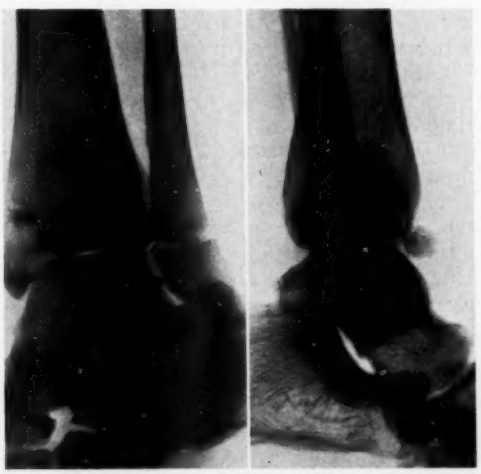

FIG. 4. Displacement of avulsed fragment of the tibial insertion of the anterior inferior tibiofibular ligament.

FIG. 5. "Rim" avulsion fracture of distal head of fibula with dislocation of the peroneal tendons.

more or less peculiar to ski injury, is one which involves the inferior and lateral rim of the distal head of the fibula. This fracture is always comminuted and the fragments may be seen in the x-ray films and they may be palpated. There is considerable displacement of the fragments which are rotated through 180 degrees. (Fig. 5.) The significant aspect of this fracture is that the peroneal tendons become dislocated anteriorly. If this dislocation does not exist at time of examination, plantar flexion of the foot will demonstrate that such dislocation may occur. This fracture should be treated by open reduction and internal fixation, which is accomplished by suturing the comminutions in place after they have been reseated; then the retinaculum is reconstructed and the ankle joint immobilized. Following surgical repair, no weight bearing is permitted for a period of six weeks.

Several years ago, Bosworth [2] described a type of ankle fracture in which the distal end of the proximal fragment of the fibula becomes impacted behind the posterolateral ridge of the tibia. This injury frequently occurs in skiing

FIG. 6. "Bosworth" fracture of distal shaft of the fibula.

and is thought to result from an external rotational force applied while the skier's weight is on the injured extremity. Figure 6 illustrates the typical x-ray finding of this injury. There is a fracture of the posterior malleolus in this particular case in addition to the fracture described by Bosworth. The surgeon should not attempt to reduce this fracture by manipulation unless he is prepared to proceed with open reduction after his manipulative efforts fail. In all of these injuries we have seen, it has been necessary to expose the fracture and pry the impacted shaft away from behind the tibia. When reduction by this method has been accomplished, a screw is placed through the fibular head and into the tibia to maintain reduction of the diastasis which is usually found to exist.

There are occasional ski injuries to the ankle in which the foot is externally rotated through 180 degrees. It is speculative as to the extent of damage to the ankle ligaments when such an injury occurs. When the deformity is corrected, the deltoid ligament often may be palpated and found to be intact. There is certainly a complete tear of the anterior tibiofibular ligament as demonstrated by the instability of the joint. We have treated these injuries by inserting a screw through the distal head of the fibula, closing the tibiofibular joint and have made no attempt at ligament repair. With this simple procedure of restoring and maintaining acceptable anatomic relationships, follow-up examination reveals a good

FIG. 7. Fracture dislocation of ankle before and after internal fixation.

functionable ankle joint which permits a return to skiing without disability. Figure 7 illustrates such a case. The figure on the left shows the dislocated ankle as it appeared after the rotational deformity was corrected. The right hand figure is the same case after reduction and internal fixation has been performed.

What happens when the unstable joint with diastasis is not properly treated? Figure 8 shows such a case two years after injury. The lateral shift of the talus is apparent, and also the tibiofibular separation. There is now some narrowing of the joint where post-traumatic arthritic changes have occurred. In this instance, the patient is a ski instructor who found his ankle too painful to continue his occupation. Arthrodesis of the joint will probably be the solution to his disability.

FRACTURES TO THE SHAFT OF THE TIBIA AND FIBULA

The spiral fracture is as much a part of the skier's vocabulary as "schuss" and "slalom." This fracture involves from one-third to one-half of the distal shaft of the tibia. The fibula is fractured at various levels and often in more than one place. Comminutions occur, referred to as "butterflies," and these comminutions frequently result in a separation of the main proximal and distal fragments so that reduction of the fracture and internal fixation requires a splicing operation.

These fractures should be considered as emergencies. Proper length must be maintained. If definitive treatment is not imme-

FIG. 8. Healed fibular head fracture with disabling persistent diastasis.

FIG. 9. Typical skiers spiral comminuted fracture of tibia and fibula.

FIG. 10. Fracture of tibia and fibula resulting from a forward thrust fall.

diately available, a traction splint should be applied for the purpose of maintaining proper length and it is better to apply too much traction than too little. In a matter of several hours, hemorrhage, exudate and fibrin, which result from the injury, may cause the muscles to become "jelled." When this has occurred, the muscles no longer behave as elastic bodies.

When a patient with such an injury is delivered to a medical facility suitable for operative work, open reduction and internal fixation offers the best method of treatment. Of the various operative procedures, a physiological one is that of circumferential fixation. The fracture site is exposed, the periosteum stripped from the fracture and Parham bands applied without pressure, but in such a manner as to exactly fit the circumference of the bone. Tightness is to be avoided for it alters dynamics. Furthermore, pressure is unnecessary, for displacement of the fracture can only occur by increasing circumference. The bands are allowed to remain in place for ten to fourteen weeks and are removed when sufficient bone healing has occurred to maintain reduction. No weight bearing should be permitted until bone healing justifies it. If this rule is not observed, angulation will occur with resulting deformity at the site of comminution. Figure 9 illustrates a typical spiral fracture. The panel on the left shows the fracture with two major central comminutions. The middle panel represents the reduced and internally fixed postoperative result. The panel on the left shows the same fracture after the bands have been removed. This film, taken five months after injury, reveals bone union adequate to permit weight bearing.

RECENT CHANGES IN SKI INJURY PATTERNS

Changes in the technic of skiing and in equipment have been associated with changes in the type of injury. Table IV shows a com-

TABLE IV
COMPARISON OF SKI INJURIES OVER A FIFTEEN-YEAR INTERVAL

Injury	1942	1957
Ankle sprain	226	248
Knee sprain	119	85
Ski fracture (fibular head)	65	43
Peroneal tendon (dislocation)	4	5
Fracture medial malleolus	3	35
"Spiral" fracture of tibia and fibula	23	31
Boot top fracture of tibia and fibula	0	8
Tear of tendo achilles	0	6

parison of a series of ski injuries seen in 1942 [10] as compared with a similar series seen fifteen years later in 1957. The striking difference is noted in the increase of medial malleolar fractures, boot top fractures of the tibia and fibula, and tears of the Achilles tendon.

In this fifteen-year interval, skiing technic has caused the heels to be forced more closely together and the skis held in a parallel position. The downhill hooks on the skis have been moved farther back toward the heels, thus preventing the heels from leaving the ski, and when a force is applied in such a manner as to bring the heel away from the ski, the cable increases its pull on the boot heel so as to resist such a force. Finally, there has been an increase in the number of people skiing all slopes and this has resulted in "moguls" being formed. "Moguls" are small mounds of packed snow which may trap the ski point on a downhill run. When this occurs, the skier is pitched forward over his toes.

The injuries which result from the falls thus accounted for, are due to a forward thrust. The force of torsion is a relatively minor factor in such injuries. Prior to 1952, we did not see a single ski injury in which the Achilles tendon was torn. Since 1952, we have seen twenty-eight of these injuries. This new force, when applied to the extremity which is secured to the ski by well fitting boots with interlacings, frequently results in a fracture of the tibia and fibula at boot top level. Figure 10 illustrates such an injury. In this case, the boot was not removed when taking the roentgenogram and one can see the level of the boot top as it is related to the level of the fracture.

Tears of the Achilles tendon have occurred in twenty-eight persons in our area since 1952, as a result of the skier being pitched forward over his ski tips. Twenty-four were men and four were women. The youngest skier was twenty-two years old and the oldest fifty-two. Exactly half of the patients were under forty years of age. In no instance was there injury to major blood vessels. Whenever the plantaris tendon was represented as a separate structure, it was found to be intact. A simple undisplaced fracture of the medial malleolus was frequently found to be a concurrent injury.

The torn tendon has presented a similar type of lesion in all cases. The major tear appears at a point 3 or 4 cm. proximal to the tendon's distal insertion. However, there is a shredding of the tendon and independent bundles of the tendon are found to be torn at different levels over a distance of several centimeters.

Surgical repair is carried out as soon after injury as convenient. We have used a criss-cross type of suture with 0 silk, to maintain proper length. The knots are tied laterally and medially to the tendon at the level of the major tear. Then using 40 cotton sutures, the individual bundles are identified and approximated at the various levels, proximal and distal to the major tear. The tendon sheath is carefully closed around the repaired tendon. A plaster cast is applied which extends from mid-thigh to the toes, holding the knee in 20 to 30 degrees of flexion and the foot in 15 degrees of plantar flexion. This type of immobilization is maintained for six weeks.

It is interesting to note that in twenty-three cases in which follow-up studies have been available, all patients have continued skiing the following year and there have been no recurrences of this injury.

PREVENTION OF SKI INJURIES

Information recorded by the Ski Patrol has been valuable in determining the most common factors which may be responsible for or relating to ski injuries. The patrolman completes a questionnaire after delivering the casualty to the medical station. Figure 11 represents the standard form which is used.

During the past five years the Ski Patrol at Sun Valley has administered first aid and provided transportation for an average of over 200 casualties each year. In the words of the skier, the cause of injury is as follows:

1. Out of control	52
2. Ruts and "moguls"	23
3. Poor visibility	16
4. Obstacles	8
5. Collision	7
6. Racing or training for racing	5
7. Faulty equipment	5

It is not entirely accurate to state that the reasons cited represent the cause of injury. It might be stated better that these factors are the reason for a fall. Certainly many ski falls occur in which no reportable injury occurs.

Further study regarding the factors which cause a skier to fall, reveals significant information not shown. It has been said that one can set his watch by the time the injuries come in. This is not entirely true but it is

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Sun Valley Ski Patrol Accident Report

Name and Home address of injured _____

_____

Date of arrival at Sun Valley _____ Room No. _____

Date of arrival at Ketchum _____ Address _____

Date of accident _____ Exact Time _____

Exact location of accident _____

How steep was place where accident occured? _____

Your opinion of cause of accident _____

How fast? _____ Experience? _____

Tired? _____ How many days skiing at Sun Valley? _____

How many hours had injured been skiing on day of accident? _____

A. M. _____ P. M. _____

Had injured been warned of possible accident? _____ By whom? _____

Was ski equipment and boots adequate? _____

Type and name of binding? _____

Weather conditions on date of accident _____ Visibility _____

Snow conditions at place of accident _____

Was injured in Ski School? _____ Private lesson? _____

Skiing independently? _____ Racing? _____ Training for a race? _____

Nature of first aid _____

By Whom? _____

Types of transportation from accident to hospital _____

Comments by Patrolman: _____

_____

By _____
Sun Valley Ski Patrol

FIG. 11. Ski patrolman's questionnaire form.

sufficiently accurate that medical appointments and nursing schedules are geared to fit the periods of maximum work load. The highest incidence of injury occurs at noon and at 4 P.M. This coincides with the observation that the highest rate of injury also occurs after three hours of skiing. (Figs. 12 and 13.)

There can be no other conclusion from these findings than that fatigue is a real factor in the cause of injury. The ability of the skier, therefore, to recognize fatigue and to resist the temptation of that one last run will contribute substantially to a decrease in the rate of injury.

Carelessness. This factor is never reported by the patient as being a cause of injury, yet a significant number of injuries are unmistakably due to it. The skier should be aware at all times of the potential danger and threat of injury that the ski lever arm represents. Many serious fractures of the tibia and fibula have resulted from a simple fall after losing balance when there has been no forward motion. The skier may finish a run and stand still. In reaching to the ground for a fallen object, his skis may become crossed and a slight slip causes a loss of balance. The underneath ski is fixed by the crossing and as a fall occurs a fracturing force is applied to the extremity. Injuries similar to this are not infrequent. Also the skier may permit himself to be distracted in the course of a downhill run. Any incident which divides his attention may result in a situation which can cause a fall and an injury.

Experience and Injury. The highest incidence of injury occurs in the beginner group. The incidence again rises sharply in the group of

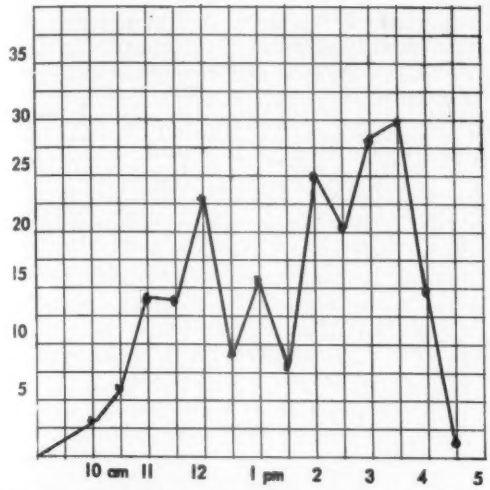

FIG. 12. Number of injuries related to the time of day of their occurrence.

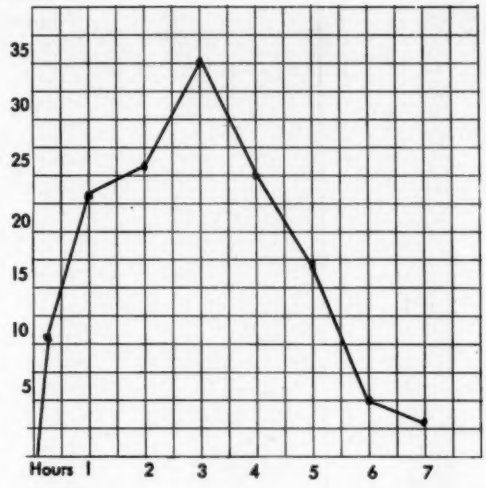

FIG. 13. Number of injuries related to hours of skiing prior to injury.

skiers who have had from two to five years' experience. With more experience and probably more accurate evaluation of skiing ability, the incidence drops off substantially. Figure 14, is a graph which illustrates the number of injuries as they are related to years of experience.

Equipment. Repeated ski counts in the Sun Valley area indicate that slightly more than 70 per cent of the skis are equipped with some type of safety or release binding. The Ski Patrol records indicate that in one season, eighty casualties used such release bindings and 138 did not. If one were to argue that release bindings were not significant in preventing injury, the ratio should be reversed. Further inquiry in the group of eighty who were injured and who used release bindings indicate that faulty adjustment of the bindings was a contributing cause. The bindings which had not been properly adjusted or which had been tightened purposely to prevent release, should not properly be classified as release bindings. In the interest of safe skiing, every skier should have a thorough understanding of the mechanism of the binding he uses and should carefully adjust the mechanism before starting his day of skiing.

In addition to the usual release mechanism which protects the skier from torsional forces, inventions have made available certain bindings which permit release when a forward thrust is applied. This force occurs when the skis are driven into a "mogul" and the skier is pitched forward over his ski tips. Interval ski counts have been made during the past two years and over half of the skis in our area are now equipped with such a mechanism. It has been observed that the incidence of tears of the Achilles tendon has shown a corresponding drop of 50 per cent during this same period.

Instruction. Over a five-year period, 320 injuries occurred in ski school. This includes all

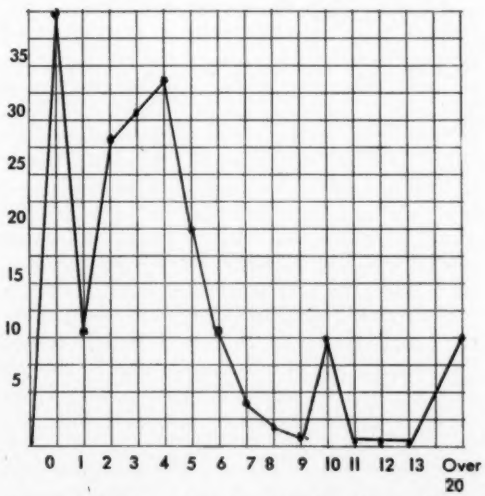

FIG. 14. Number of injuries related to the number of years of skiing experience prior to injury.

FIG. 15. Osteoporosis typical of healed shaft fractures after one year.

classes from the beginner group through racing classes. During the same period of time, 676 injuries occurred in the group who were skiing independently. It is estimated that the total number of skiers were about evenly distributed in these two groups. It would seem, therefore, that there is an added element of safety in obtaining instruction. If the element of liability could be eliminated, this ratio of injury might conceivably be reduced further. The ski school may advise the beginner as well as the more advanced skier regarding his or her equipment and may point out faults which could contribute to controlled skiing and to injury, but there must be a reluctance to active adjustment of bindings for obvious reasons. Unfortunately, law suits can be a deterrent to humanitarian impulses. One can be lost in the confusion of the argument as to the liability of acts of omission versus the acts of commission.

Protection of Injured Joints. Thorndike1 [2] has demonstrated the protective importance of the Duke Simpson adhesive support when applied to the knee joint of football players. This superb support has prevented many knee injuries in skiing also. Where there is a history of previous knee injury, or a previous operative procedure resulting in relative quadriceps weakness, downhill skiing should not be considered without this type of knee support. It is not uncommon to see the strips of tape which protect the medial aspect of the joint, completely torn following a ski fall, leaving the knee itself uninjured.

The Gibney type support for the ankle may be of added effectiveness if spiral strips of tape are applied from a point behind the malleoli so as to extend above and below the ankle joint level. The decelerating influence, that such protective tape support provides when a force of torsion is applied to the joints, often makes the difference between disabling injury and an inconsequential fall. The forces of the fall are distributed more equally to all components of the extremity rather than to one point.

When is it safe to permit the injured skier to return to skiing, in the interest of preventing recurrent injury? This has been discussed briefly regarding sprains. Over a period of years we have made the observation that recurrent fractures of tibial and fibular shafts, one year after the initial fracture, violate the laws of coincidence. This occurrence does not relate to the method of initial treatment, that is whether internal fixation or closed treatment was originally used. For several years we have made routine comparative x-ray studies of the injured bones as compared with the opposite uninjured bones. Lateral and anteroposterior x-ray studies are made using the same radiological technic in both instances. While this is not a method of measuring osteoporosis with scientific accuracy, the radiologic findings are so obvious that one cannot deny that at the end of twelve months the bone with the healed fracture in its shaft is still demineralized. This finding bears no relationship to muscular rehabilitation, for measurements of size and power in the two extremities may be equal. Figure 15 is an example of this finding. Even in a poorly reproduced print it is obvious that the panel on the right is a contrast to the opposite side. It is a responsibility of the surgeon to advise the patient of this relative weakness of the bone to resist a force of torsion. Either skiing should be avoided until remineralization has taken place, or precautionary measures relative to properly adjusted bindings and carefully controlled skiing should be observed.

SUMMARY AND CONCLUSION

The subject of ski injury is discussed giving consideration to the incidence of injury and

ype of injury. The skiing injury itself is considered only as a torsional type of injury to the ower extremities which is, of course, peculiar o this sport. In this respect, certain specific njuries are described and their diagnosis and reatment outlined. Certain factors which contribute to a relatively high incidence of injury re enumerated and if the interpretation of the ignificance of these factors is correct, attention o these factors may lower the incidence of njury materially.

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Can Skin Diving Be Made Safe?

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IT has become increasingly common in the past few years, particularly on the West coast, to read newspaper headlines such as "Skin Diver Drowns While Trying Scuba Unit in Surf for First Time."

In an effort to decrease the mortality statistics (one death per month in California) of my favorite hobby, skin diving, I would like to point out a few basic, intelligent and common sense rules of behavior for divers. Many of the tragedies which have occurred are a result of man's basic incompatability with underwater life. They are a result, in large part, of ignoring the physical laws which govern the physiological reactions of the body to gases under pressure. In presenting these causes and effects, I hope to make it very clear that there is no reason to believe that man will ever be capable of advancing the underwater frontier by diving into pressure, whether it be with "hard-hat" deep-sea diving rigs or scuba (self-contained underwater breathing apparatus) units. The use of such free-diving mechanisms as the bathyscaphe and remote underwater television cameras is of infinitely more practical value and will probably be unaccompanied by needless loss of life.

CAISSON DISEASE

This is "the bends" caused by an increased volume of nitrogen in solution in the blood stream under pressure. (A gas dissolves in a liquid in direct proportion to its partial pressure above that liquid, and exerts the same pressure as if it occupied the space alone.) After a length of time, when pressure is released, the nitrogen, if decompression is not slow enough, may form bubbles in the capillaries and cause ischemia with local damage. The areas of worst damage are the "tight" tissues with poor blood supply, such as tendons, and the areas most sensitive to pressure, such as the spinal cord. The symptoms are pain (over 90 per cent of cases), pulmonary edema with coughing and choking, and in severe cases nerve paresthesias and paralysis. This disease, or accident to be more accurate, is a result of both time and pressure. The standard decompression tables of the U. S. Navy give an accurate picture of what may be accomplished with the standard 70 cubic feet scuba tank of compressed air. Times are measured from the time of leaving the surface to the time of leaving the bottom. The Navy's rule of thumb is: From 120 to 140 feet, limit diving time to fifteen minutes (do not descend faster than 25 feet per minute as a general rule). Beyond 140 feet, decrease diving time by two minutes for every 10 feet. Ascend at a rate not to exceed 25 feet per minute. Stop at the 10 foot level for decompression and spend five minutes there for every 10 foot increment beyond 120 feet, with an absolute limit of 200 feet. This rule of thumb table is on the safe side as far as decompression time goes and was designed for that purpose, when no recompression facilities are available (as in practically 100 per cent of amateur sport diving). A brief computation will show that below 170 feet it is impossible to

Depth (ft.)	Time (min.)
30	Unlimited
40	120
50	78
60	55
70	43
80	35
90	30
100	25
110	20
120	15

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descend at the prescribed rate and have any time whatever on the bottom before having to start the return trip. This is one of the main reasons that no amateur diver should ever (in any but lifesaving emergencies) dive below 150 feet. This opinion is shared by members of my own skin diving organization, the Marin Skin Divers, Inc., who recently amended their constitution to forbid any member from diving below this level without the approval of a two-thirds majority of the Club membership, and such dives are for medical research only.

Zero-decompression diving is the term used to describe a dive in which the only decompression necessary is the 25 foot per minute rate of ascent.

NITROGEN NARCOSIS

This phenomenon, romantically called by Capt. Cousteau "raptures of the deep," is a peculiar result on the body of nitrogen under pressure. This gas, completely inert at one atmosphere pressure, causes euphoria and intoxication similar to that of alcohol with the same dulling of judgment. In some divers this may appear at as little as 150 feet and in others at as much as 200 feet or more, but it *may* affect any given person at any level, depending on his physical and mental condition on different days. Its very insidiousness is its danger, being also like alcohol in that respect. A diver may be perfectly aware that he has only three or four minutes to stay at 200 feet, but may be so affected by the "raptures," that he cannot even read his watch clearly. This, then, is a second reason that no amateur diver should ever dive below 150 feet.

AIR EMBOLUS

Boyle's law of gas behavior states that if the temperature remains constant, the volume of a gas varies inversely with the pressure. Each 33 feet that a diver descends below the surface of the ocean adds one full atmosphere of pressure on the air he has within his body: surface, one atomsphere; 33 feet, two atmospheres; 66 feet, three atmospheres; 99 feet, four atmospheres, and so on down. A human lung that is full at the surface would only be half-full at 33 feet, one-third at 66 feet, etc. Conversely, a human lung half-filled at 33 feet and brought to the surface rapidly without exhalation would be completely filled at the surface. The lungs need only be one-third filled at 66 feet to be filled at the surface. It is now obvious what happens when a panicky diver takes a deep breath of compressed air below the surface and swims up rapidly. Marked overdistention may occur and cause mild rupture of the alveoli and even pulmonary hemorrhage in a mild case. In severe cases violent shattering of the lung tissue and pulmonary veins occurs, with introduction of air into the vessels, thus the name "air embolus." Prophylaxis of this accident is relatively simple: "Never ascend while holding your breath. Breathe freely all the way up." As little as 4½ feet of water will exert a pressure of 100 mm. Hg, and such pressure is capable of rupturing any lung under the right circumstances.

Substernal and diaphragmatic pressure will normally give the diver adequate warning to exhale, but the diver who is panicky may have practically a spasm of the glottis. The actual pain associated with tearing of the lung tissue is not severe, and if pain is the first symptom there is already damage to the lung.

OXYGEN POISONING

Breathing 100 per cent oxygen under increased pressure, as is done with the so-called rebreathing type of scuba, may cause this accident. If the diver is working hard, swimming fast or doing salvage work, oxygen under pressure may cause nausea, headache, muscle twitching, convulsions and coma in as shallow a depth as 30 to 50 feet. Susceptibility varies tremendously among people and therefore this type of apparatus should not be allowed below 30 feet. Symptoms subside when the patient is removed to reduced pressures.

DO'S AND DONT'S OF SKIN DIVING, AND THE REASONS

1. Be boringly familiar with your equipment and its limitations. There is no way to overemphasize the importance of doing the right thing instantly, without having to think consciously about it. Herein lies a major key to safe diving.

2. Never overestimate your own capabilities as to swimming ability, endurance and physical condition on any given day, and reappraise that capability as often as necessary to make sure exhaustion will not become a major hazard to the day's diving.

3. Use a float. An old inner tube is perfectly adequate; it not only serves as a place to rest and regain strength after a strenuous dive but also is very handy for storing fish stringers, cameras, spear guns and other diving gear.

4. Do not dive alone. Many divers have literally had their lives saved by a buddy. Dive in pairs, with the back man keeping an eye on the front man and trade places in mid-dive.

5. In scuba diving, wear an accurate depth gage and waterproof watch. This needs no comment.

6. Avoid very rough water. A diver was drowned this year because his eagerness to try out his new equipment overshadowed sensible caution about diving in rough water in bad weather. There will be lots of good diving days. Use common sense.

7. Do not dive if you have a cold. Lack of patency of the eustachian tubes may lead to ruptured ear drums if pressures are not equalized. Even if nasal decongestants allow equalization, nasal purulence may be carried into the middle ear.

8. Be very careful of heavy kelp. One death in the Northern California area was due to this trouble when the diver became entangled in our heavy "bull kelp" and drowned before he could be extricated.

SUMMARY

Most, if not all, skin diving fatalities are caused by accidents and not diseases. Prophylaxis, then, is much more important than treatment because of the simple fact that drowning intervenes before the victim can be brought to medical attention in the severe cases. In the milder ones treatment is usually unnecessary. "The bends" is the exception and can be handled only by the nearest Navy decompression chamber and the Navy personnel familiar with it. No amateur diver should ever dive below 150 feet with a single-tank scuba. A very large majority of diving fatalities are absolutely preventable if adequate education and experience with equipment precedes actual ocean diving.

NAVMED-P 5054, "Submarine Medicine Practice," obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. for $2.00, contains a tremendous amount of information and is strongly recommended for further reading by those interested.

Boxing Injuries

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THE injuries which occur in boxing represent many types and degrees of trauma. Those organs and tissues which are most exposed bear the brunt of this trauma, although any part of the body may at times be injured. Of the exposed and unprotected areas, the forehead, periorbital regions, face, mouth, nose, ears and hands are most frequently involved, although the more protected organs such as brain and kidney are particularly vulnerable to trauma from boxing.

It seems incredible that the many scientific groups and organizations which have pioneered and made so many valuable contributions to trauma in other hazardous occupations and industries, have not become more interested in athletic injury. Certainly, there is no more challenging area in traumatology than sports injuries.

Until recently, accurate information and reliable statistics in competitive sports have been difficult to obtain. This is largely due to the lack of any medical program for the supervision and regulation of these sports. This applies particularly to amateur and professional sports. There are rare exceptions in intercollegiate sports as exemplified by the Harvard group, under the direction of Thorndike [1], in which a well organized medical program has been in existence for years and has provided excellent medical facilities for the diagnosis, evaluation and definitive care of athletic trauma. Medical interest in boxing, until recently, has been very lax and little thought or concern has been given to the safety and welfare of the boxer. Many factors obviously have contributed to this apathy, the most important of which is that the very nature and concept of boxing is contrary to medical regulation or supervision. Unfortunately, there has been little interest shown by physicians and sports officials, or by the medical profession generally, in the medical aspects of professional boxing. Until recently there were no available statistics or data sufficiently accurate or informative enough to be of value in determining the medical status of boxing. Furthermore, there are factors inherent in boxing which have made it difficult to plan or establish any long range or satisfactory medical program for this sport. Unlike baseball, football, basketball, etc., which are team sports, boxing is an individual sport; it is not a seasonal but a year-round sport, and lastly, the average boxer is a peripatetic globe trotter and does not confine his ring activities to any one state or locality.

It is generally believed by the laity and many physicians that fatalities and serious injuries in boxing far outnumber those in any other body-contact sport. Gonzales [2], former pathologist and medical examiner of the City of New York, in a report on fatalities in competitive sports (based on a study over a thirty-two–year period from 1918 to 1950, inclusive, in which he performed autopsies on athletes whose deaths resulted from athletic trauma), found that there were more deaths in baseball, forty-three, and football, twenty-two than in boxing, twenty-one. His conclusions based on this study were as follows:

"Thirty-two years of boxing competitions have produced fewer deaths in proportion to the number of participants than occur in baseball and football, and far fewer deaths than occur from daily accidents. It seems that the moral and physical benefits derived from boxing far outweigh the dangers inherent in it or any of the other competitive sports."

Despite this relatively favorable report, there were seven deaths among professional boxers in New York State during the seven-year period from 1945 to 1952, inclusive. These deaths, un-

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fortunately, were unduly publicized by the press, radio, and more recently, through the medium of television. Skepticism and doubts by many sports-minded individuals and ardent boxing enthusiasts were being expressed. Further opposition by those who have traditionally opposed boxing in any form, insisting that it could never be made a safe and humane sport, served only to confuse and prejudice the thinking of fair-minded and impartial observers and officials. Added to this confusing background were the usual problems of the cost and financial responsibility of any worth while medical program for boxers. The boxer could not afford and the clubs and promoters could not be depended upon to finance and maintain such a program.

The State accepted its responsibility for and discharged its obligations to the boxer by the appropriation of the necessary funds for the establishment and maintenance of the first comprehensive long range program for boxing. A brief outline and discussion of the organization and functions of the Medical Department and its accomplishments over the past seven years during which time most of the measures and recommendations have been in operation, form the basis of this report. Also included are a statistical analysis of the medical results achieved during this period, and a discussion of certain clinical studies and investigations of various injuries and trauma common to boxing.

The first Medical Advisory Board for boxing was formed in New York when Governor Dewey appointed this body in 1948. It consisted of nine members, including a chairman, outstanding specialists from the medical schools and the leading hospitals in the State. These authorities in sports medicine included a neurologist, psychiatrist, orthopaedic surgeon, ophthalmologist, internist, a specialist in industrial medicine, a general surgeon and a dentist, all of whom were experts in those fields of medicine which pertain to the medical aspects of boxing.

The duties of the Medical Advisory Board are: the formulating of plans and standards for the medical examination of boxers; the recommendations of various safety measures which may be necessary for the adequate protection of the boxer in the ring; the recommendation to the Commission of a panel of physicians for the examination of boxers and wrestlers; the preparation of medical record forms such as the licensing examination forms, accident report forms, and a modern medical unit file system.

In addition, the Medical Advisory Board makes recommendations to the Commission for the staffing and equipping of a modern medical office with electrocardiograph, x-ray facilities, fluoroscope, electroencephalograph, a laboratory equipped for performing examinations of blood and urine, and two full time technicians skilled in operating these highly complicated instruments.

Medical requirements and safety regulations which have been in operation during this seven-year period are indicated herein. Most of these have been presented [3] and discussed [4] in previous publications and only those which need additional emphasis will be dwelt upon.

The medical requirements of boxers, judges and referees are as follows:

1. Annual physical examination, including electroencephalogram, roentgenograms of the heart and lungs, and examinations pre- and post-bout.
2. Two physicians at ringside for all bouts.
3. Mandatory electroencephalographic and neurological examinations post-bout for all boxers who sustain a "knockout."
4. Each boxer is required to wear a properly fitted mouthpiece during each bout.
5. Re-evaluation of both the boxing and medical records of any boxer who sustains six consecutive losses or three knockouts—a candidate for probable retirement.
6. Semi-annual physical examination of referees and annual examination of judges.

There are now thirty-six Commission-approved physicians for the examination of boxers in New York State. There are two full-time trained technicians, who take roentgenograms, electrocardiograms and electroencephalograms and do the routine laboratory work required for boxers and the officials. The medical department is completely equipped with all the facilities and instruments necessary for the physical examination of the boxer.

Each boxer, before being licensed to box in New York State, must receive and pass a very rigid annual physical examination, including routine x-ray examination of the heart and lungs, electroencephalogram, examination of the blood and urine and other special examinations as indicated. Special attention is given to examination of the eyes with a minimum

requirement of 20/100 vision in either eye, and which can be corrected to normal with glasses, with no demonstrable pathologic condition in either eye. Additional routine examinations include the physical examination five-days pre-bout, the noon-day weigh-in and immediate examinations pre- and post-bout. These findings are recorded on appropriate record and injury report forms. Special attention is given those boxers who have sustained a knockout, and they are required to have a neurological examination and an electroencephalogram before reinstatement.

All boxers who are susceptible to recurrent injuries, or who have sustained six or more consecutive losses are carefully evaluated by the Commission and re-examined by our Medical Department. Such boxers are considered candidates for serious injury, and accordingly, most of them have been medically disapproved by the Medical Advisory Board and retired by the Commission. It is believed that this precautionary measure has saved many boxers from serious injury or possibly a fatality in the ring. Another valuable safety measure to spare the boxer further and possibly more serious injury is the timely intervention by the referee in stopping the fight either on his decision or the decision of the ringside physician. Even today far too many fights are allowed to continue when the boxer is helpless with his arms dangling at his sides and taking an unmerciful beating by his opponent. Such an uneven and one-sided contest should be halted minutes earlier, rather than seconds later.

The safety measures and equipment required at ringside are indicated as follows:

1. A new type of ring padding to replace the old felt pad.
2. Substitution of 8 ounce for 6 ounce gloves for all except championship bouts.
3. Properly fitted mouthpiece to be worn by the boxer during the fight.
4. A portable resuscitator with oxygen equipment available at all rings.
5. Thirty day automatic minimum suspension for any boxer who sustains a knockout or technical knockout or other injuries of sufficient severity.
6. Interruption of any bout, except a championship fight, wherein the opponent sustains more than two knockdowns in any one round. Both of these knockdowns must be for the mandatory 8 counts.

The replacement of the old felt padding by the new plastic "ensolite" fiber board pad, under the ring canvas, has largely eliminated fatalities from serious injuries to the head, which were so prevalent when the old felt pad was in use. This plastic ensolite pad was the result of over two years of exhaustive research by the Cornell Aeronautical Laboratories of Buffalo, New York, under the direction of its chief engineer, Mr. Edward Dye, under contract authorized by the New York State Athletic Commission.* There is no longer in evidence the back and forth rocking of the head on impact of the occiput against the ring canvas which was commonly observed before this new type of pad was introduced. It is generally believed that this so-called acceleration-deceleration phenomena which resulted from a knockout, as previously described, was the cause of direct and contra-coup injuries and serious hemorrhages in the brains of boxers. The mortality rate has been reduced to zero and the incidence and severity of injuries to the head in boxers have been significantly lower since this safety device was introduced.

The automatic thirty-day minimum rest period which is also honored by all states and municipalities which have a reciprocal working agreement with the New York State Athletic Commission, prevents the injured boxer from getting back into the ring before he has been pronounced physically fit for fighting. The various commissions are simultaneously notified by bulletin when the boxer has been medically approved to resume fighting. (Table 1.)

CASE REPORTS

There were 325 knockouts: boxers who took the 10 second count and were counted out during the seven-year study. All of these boxers, except ten, were able to arise from the floor and walk to their corners unaided requiring no further definitive treatment except the usual electroencephalogram and a thirty-day medical suspension and re-evaluation before being permitted to box again. There were ten boxers, however, who sustained more severe concussions and were unconscious for a period longer than ten seconds. These were hospitalized from twenty-four hours to ten days. All of them were retired from boxing because of the severity of their injuries to the head. There were two

* Editor's note: See article by Mr. Dye elsewhere in this issue.

TABLE 1
MEDICAL AND STATISTICAL REPORT OF INJURIES AMONG PROFESSIONAL BOXERS IN NEW YORK STATE (A SEVEN YEAR STUDY—1952 THROUGH 1958)*

Data	No. of Cases	
Total number of participating boxers	11,173	
Knockouts	325	
Knockouts requiring hospitalization		10
Technical knockouts	789	
Secondary to injury, fight stopped		557
Fight stopped as result of inability to defend self, fatigue, exhaustion, outclassed, etc		232
Lacerations and contusions (trauma to the soft tissue)	1,010	
Injuries to the eye	19	
Corneal injuries		13
Detached retina		6
Fractures	38	
Nasal bones		16
Metacarpals		14
Jaw		4
Phalanges		3
Ankle (external malleolus fibula)		1
Dislocations (shoulder joint, anterior)	4	
Miscellaneous—"boxer's knuckle"	18	
Retirements—poor records, neurological disorder, heart disease, etc	148	
Total mortality	0	

patients who were hospitalized for more than one week because of severe injury to the head and damage to the brain.

CASE I. S. E., a twenty-four year old boxer with a poor boxing record of eight losses, three draws and two wins, fought a six-round fight at St. Nicholas Arena on October 3, 1952. There was no knockout and he lost the fight by a decision. After returning to his dressing room, chronic seizures of the right upper and lower extremities suddenly developed and he became unconscious. He was immediately transported to St. Clare's Hospital where a neurological examination revealed the deep reflexes to be markedly exaggerated; the pupils were unequal with the left pupil dilated and right pupil contracted; lumbar puncture disclosed clear spinal fluid but markedly increased pressure, 330 mm. of water. The patient was unconscious for three hours after which he became lethargic and drowsy but responded to questions coherently. X-ray examination of the skull and electroencephalograms were within normal limits. Blood pressure was elevated, 150/90 mm. Hg.

The diagnosis was severe cerebral concussion. The patient was hospitalized for ten days and neurological examination was within normal limits on discharge. Because of the severity of this boxer's injury to the brain, he was retired from boxing.

Comments. This boxer would not now have been allowed to box but would have been retired because of his poor boxing record.

CASE II. B. C., a twenty-two year old lightweight boxer, had fifty fights since September, 1952. He won forty-three with five losses of which two of the most recent were by technical knockout and two were draws. This boxer was taking a severe beating about the head in the eighth round. He went to his corner unaided, complained of headache, twitching of muscles of arms and face developed and he became unconscious. The resuscitator was used at ringside and consciousness returned in about ten minutes. He walked back to his dressing room unaided and immediate hospitalization was advised. He refused and returned to his home in Springfield, Massachusetts. Three days later he was seen by a neurosurgeon and at that time complained of severe headaches and was hospitalized. Electroencephalography was performed and was negative for abnormalities. Neurological examination revealed no localizing signs but showed evidence of choking of the discs and papilledema. The next day a lumbar puncture was performed. The spinal fluid was xanthocromic and showed markedly increased pressure, 380 mm. of water. On July 29, three days later, his headache increased, as well as choking of the discs, and he showed bilateral Babinski reflex. Cerebral arteriography was performed and revealed a right-sided lesion. Tentative diagnosis of a right-sided subdural hematoma was made. Surgery was performed on the same day, during which a large right-sided subdural hematoma was evacuated. The immediate postoperative course was satisfactory. The patient's lethargy disappeared as well as headaches and other neurologic signs. He was discharged ten days later with no residual neurological signs or symptoms, and was retired from boxing because of severe craniocerebral trauma and subdural hemorrhage.

Comments. This boxer's record reveals that he had probably fought too frequently during the previous year and in the two previous bouts which he had lost by technical knockouts, he had sustained considerable punishment to the head. In addition, the electroencephalogram taken pre-bout revealed beginning evidence of deterioration and paroxysmal dysrhythmia on hyperventilation with a slightly slow record anteriorly.

CRANIOCEREBRAL TRAUMA

Acute cerebral trauma and its sequella, chronic traumatic encephalopathy, have long been considered the most frequent serious complications of boxing. The so-called punch-drunk syndrome described by Martland [5] over thirty years ago, has become symbolic of brain injury. It has never been proved to be a neurological syndrome peculiar to boxers and produced by boxing. It has, unfortunately, become a slick medical cliché with which to label any boxer whose performance and behavior in or out of the ring is unsatisfactory or abnormal.

Since there has been a general lack of knowledge and information concerning acute cerebral trauma in boxers, it was hoped that we could make a worth-while study and add to our knowledge of the precise sequence of events which follows injury to the head in boxers. Accordingly, we requested and obtained information for such a study and secured the services of two well known, experienced neurosurgeons for this project. The junior member of the team, who accepted a three-year assignment as ringside physician, is familiar with neurological trauma in boxers and has read and interpreted their electroencephalograms since 1948. This study was primarily for the purpose of determining the nature and effects of blows to the head and chin on the brains of boxers [6]. It involved the critical appraisal of ringside observations with the aid of cinematography, and correlating and interpreting these findings with the electroencephalographic record of each boxer. One thousand and forty-three boxers were studied and 1,400 electroencephalograms were performed during this three-year period.

Ringside Observations with the Aid of Cinematography. This study involved the repeated observation of the style, types and action of boxers engaged in fighting. In order to obtain a more critical analysis of these, moving pictures were made of these fighters and slow motion photography of segments of them were studied. The following observations were noted: (1) Performance in the ring closely parallels the physical fitness and experience of the fighter. (2) Relatively few blows in a single fight are effective, most of them falling short of their mark or striking their opponent tangentially. The majority of blows to the head are dissipated on the surface with no obvious evidence of the force being transmitted to the structures within the intracranial cavity. In an average ten-round bout, approximately 1,000 punches are struck to various parts of the body but relatively few of them are effective, as exemplified by the fact that in 100 consecutive fights, only four knockouts resulted. The entire list of 325 knockouts represents only approximately 3 per cent of the entire group of those who participated in boxing over the seven-year period.

The effectiveness of the blow is in direct proportion to the speed and manner in which it is delivered. A straight or short arc punch delivered from the shoulder is far more effective than a wild so-called haymaker swing. Blows which land on the chin or side of the head in the anterior temporal region are the most effective and produce the majority of knockouts. An effective blow to the head or chin causes a fighter to pause momentarily, lower his guard or reach for his opponent, clinch, drop to one knee or fall completely prostrate. A dazed fighter is an easy target for a knockdown blow. The knockout blow is one which renders the boxer temporarily unconscious for a period of ten seconds, during which he is counted out. Soon thereafter, within thirty seconds, he rises under his own power, returns to his corner and is able to leave the ring unaided. Complete consciousness has returned and the neurological examination is negative for abnormalities. He has no retrograde amnesia, headaches or other associated neurological signs or symptoms. This is the routine pattern which is generally observed when an opponent is knocked out in the ring.

Electroencephalograms and Their Correlation with the Boxing and Performance Record. As previously stated, 1,400 electroencephalograms were performed on this group, and 197 of the boxers had from one to six repeat electroencephalograms performed on them; repeat records were obtained as a routine check in some cases, after difficult fights in others, and by the request of the electroencephalographer in still others. Forty subjects had immediate electroencephalography performed post-bout at ringside within ten minutes after losing a fight either by knockout, technical knockout or decision.

There were two well differentiated categories of electroencephalographic patterns into which these boxers were placed: (1) The more classical or normal pattern consisted of constant, even,

well formed 10 per second alpha frequency in the parietal, occipital and temporal regions and low voltage beta activity in the frontal area. There were 1,149 cases which fell in this group. (2) The more abnormal consisted of focal or diffuse dysrhythmia and disorganized patterns with slow waves or spike formations. There were 513 boxers in this group.

Interpretation and Findings. The top-rated fighters were generally found in the normal, low voltage, fast types of patterns, whereas the lower rated fighters who suffered more knockouts and technical knockouts were found to have the more disorganized patterns. There was no significant statistical relationship between the extreme "wins" and "losses" classes and the electroencephalographic types. Peculiarly enough, the large percentage of boxers winning over 75 per cent of their bouts were found in the moderately slow, diffuse type. The total number of fights was not a factor in determining the type of electroencephalogram to be found. The electroencephalographic pattern of boxers as well as non-boxers is probably more inherent in the person than secondary to occupational pursuit. The electroencephalogram primarily serves its purpose in professional boxers in the detection of grossly disorganized or changing brain wave patterns. Capable performance in the ring is usually associated with a well organized electroencephalographic pattern, one serving to complement the other. Certainly, a fighter with electrical activity of the brain as depicted by the electroencephalogram as being persistently and severely disorganized, should be investigated neurologically before being permitted to box. However, a boxer is seldom barred from participation solely on the basis of a disorganized electroencephalographic pattern.

This study revealed that the criteria to be used in evaluating the boxer for professional fighting should be the following: (1) physical fitness as evidenced by a complete physical examination, (2) the past medical history, including neurological history, (3) past performance in the ring, and (4) electroencephalography.

During the past seven years, over 11,000 boxers have been examined and licensed in New York State. Twenty old, retired boxers were examined and 148 boxers out of the total number were retired or refused a license because of medical disability. Not one of the boxers examined revealed a typical punch-drunk syndrome. We have no evidence at hand to prove that such a syndrome exists in boxers.

RENAL TRAUMA

A preliminary report [7] based on a study of examinations of urine pre- and post-bout in 103 professional boxers at Madison Square Garden and St. Nicholas Arena revealed albumin in 68 per cent, red blood cells in 78 per cent, and hyaline or granular casts in 28 per cent of the microscopic examinations of urine specimens examined after the bout.

A more thorough and detailed study on hematuria in boxers [8] was undertaken based on the clinical laboratory and x-ray studies of 764 professional boxers who fought in New York State over a three-year period. The investigations included (1) clinical and laboratory examinations during the day of the bout, examinations of urine pre- and post-bout; (2) roentgenographic examination and urologic survey, usually by intravenous urography, of 100 boxers who had significant hematuria, pre- or post-bout; and (3) a control clinical study of boxers and other athletes who did not box.

Results. In 2,200 urine specimens taken pre-bout, red blood cells were found in 7.9 per cent; in 1,518 specimens taken post-bout, red blood cells were found in 65 per cent. The incidence of hematuria, post-bout, according to rounds is found in Table II.

The incidence of congenital anomalies and pathologic findings on intravenous urography in 100 boxers with significant hematuria, pre- and post-bout, is as described in Table III.

Exercise by itself does not account for significant hematuria; in 132 professional boxers

TABLE II
INCIDENCE OF SIGNIFICANT HEMATURIA (POST-BOUT) ACCORDING TO ROUNDS

No. of Rounds	No. of Urine Specimens	Significant Hematuria*	
		No. of Cases	Per cent
4	902	156	17
6–8	340	137	40
10 or more	276	122	44
Total.....	1,518	415	27†

* Six or more red blood cells per high-power field.
† Average.

TABLE III
RESULTS OF INTRAVENOUS UROGRAPHY IN 100 BOXERS WITH SIGNIFICANT HEMATURIA

Condition	No. of Cases	
	Right Side	Left Side
Renal abnormality	116	59
Excessive renal mobility	22	10
Hydronephrosis	18	9
Impaired outline of upper calyx	48	15
Impaired outline of middle calyx	8	10
Impaired outline of lower calyx	7	10
Impaired outline of all calyces	8	1
Contracted kidney	1	1
Congenital reduplication of kidney and ureter	1	1
Bifid renal pelvis	1	2
Absent kidney	1	..
Ectopic (pelvic) kidney	1	..
Ureteral abnormality	17	8
Scar at ureteropelvic junction	11	6
Tortuous ureter	1	..
Hydroureter (congenital)	1	..
Ureteritis cystica	1	1
Ureterocele	1	..
Reduplication of ureter	2	1

it was found only in 4 per cent, whereas in boxers who had superimposed renal trauma, it occurred in 27 per cent.

The characteristic pathological patterns on x-ray examination were the pericalyceal deformities seen both in active and retired boxers as the result of the progressive process arising from repeated trauma to the kidneys on boxing. This calyceal distortion ranges from parenchymal bleeding to scar formation with almost complete obliteration of the fornix to marked dilatation secondary to scar formation at the junction of the calyx with the pelvis. The upper calyceal system of the right kidney, and to a lesser degree, the middle and lower calyces of both kidneys are also involved at times. However, tests of renal function revealed little or no impairment of concentration unless accompanied by obstructing lesions.

Congenital renal anomalies accounted for the most severe cases of hematuria, pre- and post-bout, and when trauma is superimposed, recurrent and progressive pathologic disturbances result. Such pathologic conditions should be investigated and boxers whose x-ray, clinical and laboratory examinations reveal a progression of the pathologic process should be considered candidates for retirement.

TRAUMA TO THE SOFT TISSUE

There were 1,010 cases of wounds of the soft tissue over this seven-year period. These consisted of contusions, abrasions and lacerations, and there was no attempt made to differentiate between them because there were elements of each type in all of the wounds. In most of them, the contusion appeared to predominate, particularly in wounds about the cheek and jaw; whereas in wounds over the underlying bony prominences such as the frontal bone, supra-orbital ridge, malar eminence, zygomatic arch or chin, lacerations predominate. In wounds about the eyelids and cheek, hematomas are common.

It is significant that 575 bouts had to be stopped because of extensive injuries to the soft tissue. It was also significant that many of these lacerations and contusions were over the exact sites of previous similar injuries. The immediate treatment of these lacerations at ringside is far from satisfactory. We have banned Monsels solution, silver nitrate and adrenalin. However, other equally obnoxious solutions, greases and ointments are applied such as zinc oxide ointment, bismuth subgallate and vaseline. Thus, the wounds are not only contaminated, but their immediate treatment and definitive care is rendered difficult and the results achieved leave much to be desired. These lacerations should all be treated by thorough irrigation and with copious amounts of saline solution, adequate but not unnecessary débridement, avoidance of strong chemicals or antiseptics and meticulous layer closure using No. 5–0 plain interrupted catgut sutures in the deep layers and fine No. 5–0 silk or horsehair sutures for the skin. These sutures should be removed early to minimize formation of cicatrix.

Since all wounds heal by cicatrization, one should minimize it in these boxers, because a dense broad thick scar is an easy target and will reopen, and the density of the scar determines the vulnerability to opening when subjected to trauma. Therefore, a fine linear cicatrix will protect a boxer much better than will a broad dense deep cicatrix.

The boxers who sustain these lacerated wounds should not resume boxing before three months. However, this time limit is very diffi-

cult to put in practice as most boxers believe that a slight scar is insignificant.

TRAUMA TO BONE (FRACTURES)

There were sixteen fractures of the nasal bone, fourteen of the metacarpals (ten of which involved the right hand), and three of the phalanges. There were four fractures of the jaw, three of the mandible and one of the maxilla. The disability of the fractured hands was approximately three months, while the disability as a result of fractures of the jaw was six months.

MISCELLANEOUS OR OTHER COMBINED INJURY TO THE SOFT TISSUE AND BONE

There were eighteen cases of acute and chronic traumatic synovitis usually involving the second and third metacarpal phalangeal joints. This injury is rather characteristic and has aptly been paraphrased boxer's knuckle [9]. It consists of swelling of the skin, subcutaneous tissues and inflammation of the synovia. Occasionally, a small amount of fluid may be present in the joint and slight to moderate or marked swelling occurs. Gladden [9] has described four categories of severity ranging from simple trauma to the underlying subcutaneous tissue, to swelling and trauma involving the overlying tendon and extending down to and including the cartilage and the joint proper. He has operated on three such patients with extensive involvement and has had very good results; these boxers have resumed boxing. We have had no experience with the operative procedures. In those cases of extensive involvement we have advised hot soaks, occasional aspiration of fluid and injection of .5 cc. of hydrocortisone into the joint, and periods of rest along with appropriate physiotherapy. Most of these have responded. Some, however, have become chronic and have interfered with effective punching.

SUMMARY AND CONCLUSIONS

The medical program, safety procedures and clinical studies which have been in operation by the Medical Advisory Board and approved by the New York State Athletic Commission, have made boxing a safer sport. This is confirmed by the statistics contained herein, which indicate that in the previous seven-year period there were seven fatalities in boxing in New York State, whereas the present seven-year study reveals that there were no fatalities and relatively few serious injuries.

The study of cerebral trauma was particularly significant. No clinical or laboratory evidence was found which would substantiate the so-called punch-drunk syndrome that has so often been erroneously identified with boxers.

The studies on renal trauma were very helpful and we believe they will enable us to evaluate more critically those boxers who have a history of pre-existing renal disease. We believe that if the hematuria persists in such boxers, they should be retired.

Trauma to the soft tissue is still a major problem in boxing. There should be more stringent regulation and supervision of the handling of these injuries at ringside and improved facilities for the definitive treatment of these wounds.

It is believed that a medical program for boxing is just as necessary and beneficial as for other competitive sports and hazardous occupations, and as such, deserves the same careful consideration and concern.

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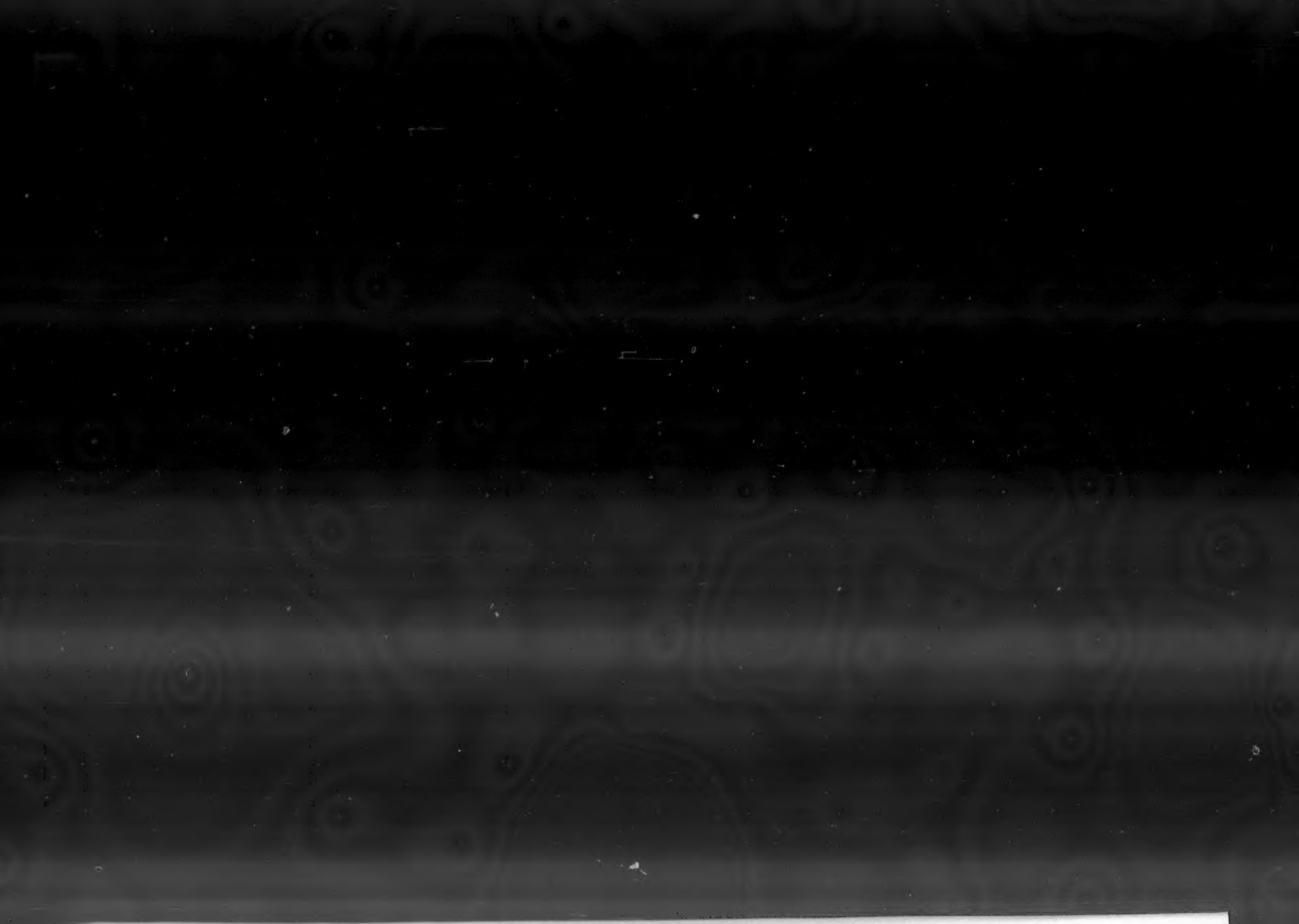
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